A PRELIMINARY STUDY IN DISCRIMINATION OF MAZE PATTERNS BY THE RAT

BY

JOSEPH G. YOSHIOKA

PSYCHOLOGY.—George M. Stratton, Warner Brown, and Edward C. Tol
Price per volume, $3.50. Cited as Univ. Calif. Publ. Psycho

A PRELIMINARY STUDY IN DISCRIMINATION OF MAZE PATTERNS BY THE RAT

BY

JOSEPH G. YOSHIOKA

A PRELIMINARY STUDY IN DISCRIMINATION OF MAZE PATTERNS BY THE RAT*

BY

JOSEPH G. YOSHIOKA

CONTENTS

INTRODUCTION

Several papers have been written regarding form and size discrimination in animals. Kinnaman (1902) found that the *Macacus rhesus* monkeys readily distinguished a food vessel of a given shape from other shapes; with given shapes, a larger size was preferred. But they failed to discriminate between designs drawn on cards. Watson (1914) found also that two *M. rhesus* monkeys discriminated a circle from a square of equal area, and a hexagon from a triangle. An inversion of the

triangle did not disturb the habit. Yerkes (1907) concluded that the dancing mouse was apparently devoid of form perception. Waugh (1910), working with the mouse, confirmed Yerkes' negative conclusion. L. J. Cole (1907) affirmed that the frog could readily establish a habit of avoiding certain food objects of a given shape. L. W. Cole and Long (1909) claimed that the raccoon could distinguish a circle from a square. Porter (1904) found that the English sparrow did not readily react to wooden boxes differing in form, but both the English sparrow and the cowbird learned to react differently to different designs on cards. The cowbird singled out a triangle from all the other forms; the sparrow failed in this reaction. The pigeon was found by Porter (1906) to be able to pick out a given form of a box among boxes of different forms. Casteel (1911) found that the turtle did very poorly in general in pattern discrimination, but two turtles discriminated vertical from horizontal lines; another two discriminated two series of parallel vertical lines of different intervals. Bingham (1913) claimed that the chick was very sensitive to size differences. Its form discrimination was also very good, but according to Bingham, form discrimination is nothing more than a keen perception of size differences. Breed's (1912) chicks confirmed Bingham's positive results. Orbelli (1908) using Pavlov's conditioned reflex method found that the dog was sensitive to form and size differences. Lashley (1912) found that the white rat could discriminate a square from a circle; and, in given circles or squares, it was sensitive to an areal difference of one fourth. Katz and Revész (1908) succeeded in establishing a circle-square habit in the chick. Révész (1924) claimed that the chick was subject to size illusion.

The method in all these experiments was visual presentation. Since the facts about the function of vision in the different animals are surprisingly little known, no positive statement can be made that in these experiments the animals were reacting primarily to visual stimuli. Particularly in the case of the rat and the maze, as has been pointed out by Hunter (1913), there

was no assurance that the windows of different forms and sizes terminating the alleys served as the exclusive differential stimuli. Hunter argued that form discrimination in rats is always pattern discrimination. The animals seem to be reacting, not to triangularity or circularity *per se,* but to a particular distribution of sensory cues in space, which was triangular or circular. Further it is generally agreed that the rat is poor in vision. Hence an experiment on form and size discrimination in the rat, where the presentation is visual, necessarily precludes any clear-cut result. Accepting, then, Watson's (1907) thesis that the rat depends mainly upon kinaesthesis, it seemed that an experiment upon the discrimination of maze patterns through the method of kinaesthetic presentation should offer with rats a more hopeful outlook. The present investigation was undertaken with this point in mind.

THE PROBLEM

The present experiment tries to answer the following questions: Is the rat able to discriminate maze patterns; or more specifically, is the rat able to discriminate an equilateral-triangular path from an irregularly pentagonal path of equal length? And if so, which pattern is preferred?

APPARATUS AND METHOD

MAZE

In order to fulfil the requirements that the two paths be of equal length, but of different patterns, the maze (fig. 1) was constructed in the form of an equilateral triangle which has the following geometrical properties: By joining the midpoints of the first and third sides (sides *a* and *c*) and again the midpoints of the third and second sides (sides *c* and *b*), a pentagon, standing on the same base (side *c*) as the triangle, and composed of two consecutive equilateral triangles, is formed whose perimeter is equal to that of the triangle. The internal angles in both

figures remain at 60°. The whole maze is made of galvanized sheet iron, 8 inches high, except the starting box and the food box, which are wooden. At one vertex (A) of the triangle the food box containing also the starting box within it is inserted.
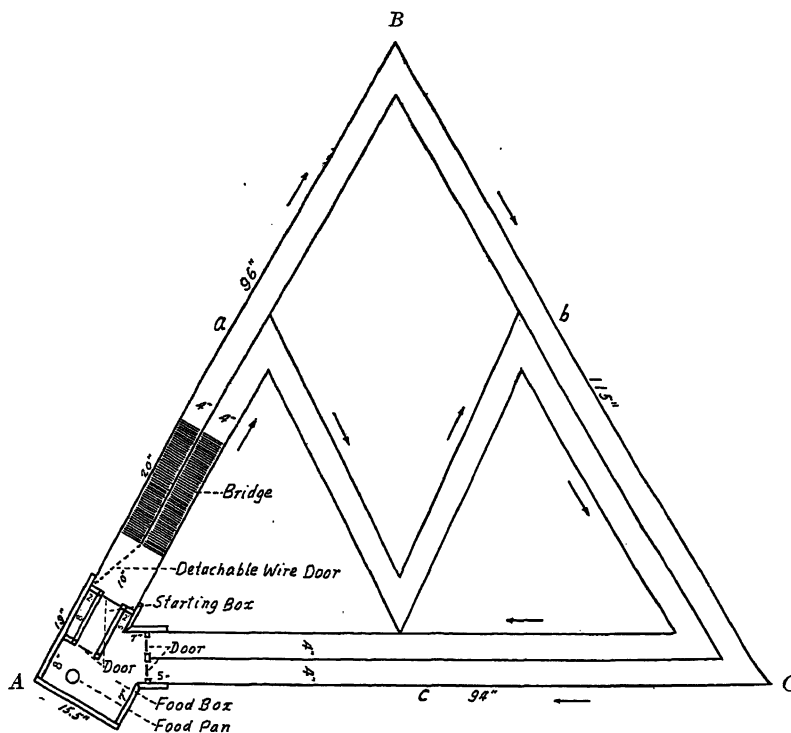
Fig. 1. Maze.

The starting box, communicating with the maze proper and the food box, has the front and back doors of sheet iron set in smooth grooves on the side posts. By means of a string tied on the top of the door and passing through a screw-eye on the horizontal bar capping the side posts, the door can be noiselessly pulled up. Where the alleys end in the food box, a pair of similar doors is placed. The left alley (hereafter designated as path 1) circuits the three sides of the triangle, and hence is triangular in shape.

The right alley (hereafter designated as path 2) starts along path 1, diverges from path 1 at the midpoint of side *a,* runs to the midpoint of side *c* parallel to side *b*; turning again it reaches the midpoint of side *b* parallel to side *a.* For the rest of its course it runs along path 1. Path 2 is pentagonal. Both paths are 4 inches wide. At the entrance of the maze the two paths have no wall between for the distance of 10 inches. Where the two paths begin to be walled off one from the other, the floor of each has a hump in it, like the top of a Japanese bridge. The roofs of these humps are 11.5 inches high and 20 inches in span, the floors coming up to the top of the maze, which is 8 inches high. On account of these humps or bridges the two paths look very much alike from the entrance. As shown in the figure, the first turn of path 1 is twice as far away from the entrance as the first turn of path 2. The floors of the bridges, inclining up as high as the top of the maze, completely screen off the view of these two turning points at the entrance. Any visual cue attached to these turning points that may influence the choice of the two paths is thus eliminated. Path 1 (including the bridge) is approximately 327 inches long as the rat runs. Path 2 should be just as long. But the passage of path 2 lies 4 inches nearer the center of the triangle, since each path has the width of 4 inches, and the pentagon is inscribed in the triangle; and, moreover, at each angle the inscribed path saves 8 inches in turning. These conditions made path 2 shorter than path 1 by 42 inches. To minimize this difference the first and third turns of path 2 were shifted 4 inches toward the angle *B.* This lengthened path 2 by 16 inches (though in so doing the internal angles were reduced from 60° to 52°). In addition the rat completing a circuit through path 2 had to travel 4 inches farther to get at the food, since the food pan was placed farther away from path 2 than from path 1. By these means whatever actual difference there remained between these two paths came well within the threshold of the discrimination of maze distance. (DL = 1/10), as proved by De Camp (1920) and confirmed

by Yoshioka (MS, 1928). The two paths could thus be considered practically as of equal length.

The task required of the rat was to make the circuit of the maze from the starting box back to the food box through either path 1 or path 2. Before the pair of bridges a ½-inch wire-mesh door could be installed at will. This door, hinged by wire rings on an iron sheet inserted between the bridges, could be pulled toward one side or the other in the fashion of a ship's rudder; thus the one path could be left open while the other could be closed. The closed path, however, was always plainly visible through the wire mesh.

EXPERIMENTAL PROCEDURE

The running was divided into two series: (1) the training series; (2) the choice series. (1) The training series involved forced runnings (by properly manipulating the wire-mesh door) through each of the two paths. It lasted for four days and on each day the animal was run alternately on the two paths (6 runs per day, 3 in each path). Hence at the end of this series each rat had been forced to run each path 12 times: 24 runs in all. (2) The choice series began the day after the training series had been completed. Two methods were employed: series *A*, the *free-learning method;* series *B*, the *daily-practice method*. In series *A* the wire-mesh door was taken off, and the rats were free to choose either path, 6 times per day for 10 days. Hence each rat had 60 choices in all. In series *B*, just before the beginning of the daily program, the wire-mesh door was put in and the rats were forced through each path once. After this short daily practice, the door was taken off, and the rats were allowed to choose, as in series *A*, either path freely, 6 times a day for 10 days.

SCORING

Since the problem was to see which of the two paths would be predominantly chosen by the rats, the constant method (method of right and wrong cases) was employed. The scores were the

frequencies of the choice of each path within the total 60 choices. The two paths were approximately equal in length, and the simple pattern of the maze involved very little learning. It is clear that time and distance scores would have had no meaning, and also that, with the absence of blinds, error scores were impossible.

RATS AND EXPERIMENTAL SET-UP

The experiment was carried out in the winter, 1926, in the Psychological Laboratory at the University of California. The maze was set in a corner of a room, where a heavy black curtain excluded the general light. Just above the bridges a 110-kw. lamp was suspended high in the ceiling of the room. This was to insure as much and as equal illumination as possible throughout the two paths, and particularly at the choice point. The room was relatively free from external noise. The rats were Wistar descendants reared in the laboratory, and at the beginning of the experiment were two to three months old. Thirty rats constituted one group, and the sexes were distributed as follows: group I for experiment I, 20 ♂ and 10 ♀, 30 in all; group II for experiment II, 22 ♂ and 8 ♀, 30 in all.

EXPERIMENTS AND RESULTS

EXPERIMENT I, SERIES A (FREE-LEARNING METHOD)

After the training series, 6 trials per day for 4 days, had been completed, group I, composed of 30 rats, was given the choice of two paths by the *free-learning method,* 6 times per day for 10 days. It was of course unknown a priori which path, triangular or pentagonal, would be preferred by the rats. It was also uncertain whether any preference would be shown. If no preference were shown, the mean frequency of the choice of one of the two paths, that is, the choice by chance, in 60 choices would be 30 ± 3.87 $(\sigma_p = \sqrt{npq})$. But actually the mean frequency of the choice of the pentagonal path by 30 rats in 60

choices was found to be 37.70 ± 1.43 (table 1). The difference between the probable and actual scores was 7.70, which was 1.9 times the sigma of the difference $(\sigma_{diff} = \sqrt{\sigma_I^2 + \sigma_{II}^2})$; hence the difference is significant. The reliability coefficient obtained by correlating the odd days with the even days was .497, but the same obtained by correlating the first half of the days with the second half of the days was as low as .225 (table 2). Within each half, however, the reliability coefficients were .913 and .801, respectively, by the odd-vs.-even method. These coefficients show that the performance in the first 5 days was a little different from that in the last 5 days. The intercorrelations (table 3) show the same thing: those along the diagonals are fairly high; the second diagonals are the next best; but as the days are chosen further apart, the coefficients become low and even negative in some cases. The daily means, when plotted, showed an ascending learning curve flattening out toward the end.

All these evidences indicate that in the last half of the series the behavior of the rats in the maze became more stabilized and relatively constant from day to day. But is this an evidence of discrimination? Frequency and recency factors might be very potent in habit fixation of this type. One path might be selected as a result of discrimination between the two paths; it might also, however, be chosen independently of discrimination, simply because it happened at the beginning to be more frequently and more recently traversed. The preference shown for the pentagonal path may thus have been due to the operation of frequency and recency factors, and not to the power of discrimination. In order to confirm or dispel such a doubt series *B* was carried out.

Experiment I, Series B (Daily-practice Method)

Group I, composed of 30 rats which had completed series *A*, was given another choice series, 6 trials per day for 10 days, by the *daily-practice method*. Just before the beginning of the

daily program the rats were forced through each path in alternate order on successive days by inserting the wire-mesh door. After this short daily exercise, the choice was given, exactly as in series *A*. The daily practice aimed at reminding the rats of the cues in each path, thus intensifying the factors needed for discrimination. Also these two forced runnings would tend to counteract the influence of frequency and recency on choice. The result showed that the mean frequency of the choice of the pentagonal path by 30 rats in the total choice of 60 for each rat was 39.13 ± 1.84, 9.13 above the choice by chance, or 2.1 times the sigma of the difference (table 1). That is, the significance of the difference increased. Also the reliability coefficient rose to .700 by the half-vs.-half method, and to .875 by the odd-vs.-even method. Within each half, the coefficients by the odd-vs.-even method were .789 and .842 respectively (table 2). Comparing with series *A*, it is seen that these reliability coefficients are much the higher. Again the inter-correlations (table 3) are all high, and this further bears out the evidence given by the high reliability. We can conclude then that the animals were really discriminating and also that the *daily-practice method* is a superior one for allowing such discriminative propensities to appear.

Comparing series *A* with series *B*, the correlation between these two series was found to be .796 (table 4). The correlation between the two first halves was .296, but between the two last halves was .762. The last half of series *A* approached closer to series *B*. Perhaps this was to be expected, since series *B* might be considered nothing but the continuation of series *A*. The scores in series *B* may very well have been mainly due to discrimination, but the better discrimination here may have been due to the practice effect carried over from series *A*. To examine this possibility experiment II was carried out, where series *A* and *B* were given in a reversed sequence, that is, series *B* first, followed by series *A*.

Experiment II, Series B (Daily-practice Method)

A new group of 30 rats (group II) was given the same pre-liminary training series as in experiment I, and then a choice series of the daily-practice variety. The result showed that the mean frequency of the choice of the pentagonal path by 30 rats in the total choices of 60 for each rat was 41.03 ± 2.07 (table 1), 11.03 above the choice by chance, or 2.5 times the sigma of the difference. The difference between the obtained scores and the most probable scores to be obtained by chance was increased in significance, proving the efficacy of the *daily-practice method* in a discrimination problem of this type. The reliability coefficient by the half-vs.half method was .788; by the odd-vs.-even method, .948 (table 2). Within each half, the coefficients by the odd-vs.-even method were .891 and .886 respectively. The inter-correlations (table 3) were very much higher throughout than in experiment I, series *A* (given in the same sequence). To see what influence series *B* has on series *A*, series *A* was given immediately after series *B*.

Experiment II, Series A (Free-learning Method)

Here the rats after having completed series *B* were given the choice by the *free-learning method*. The mean frequency of the choice of the pentagonal path by 30 rats in the total choices of 60 for each rat was found in this series *A* to be 36.87 ± 2.11, 6.87 above the choice by chance, or 1.6 times the sigma of the difference (table 1). The significance of the difference between this and a 50-50 choice was much less than in the choices for series *B*. The reliability coefficient by the half-vs.-half method was .866; by the odd-vs.-even method, .957. Within each half, the coefficients were .906 and .948 respectively by the odd-vs.-even method (table 2). The intercorrelations (table 3) were consistently high. The stability of performance was very much in evidence, but the degree of discrimination decreased materially

as compared with series B. Hence it seems that the stable performance here witnessed may well have been due in part to frequency and recency factors rather than to discrimination.

Comparing series A and B in experiment II, the correlation between these two series was .977, much higher than the similar correlation found in experiment I (table 4). The correlation between the first halves was .772, but between the last halves it was .679. It seems that, toward the end of series A, the practice effect of series B, helpful for discrimination, tended to be forgotten, and the animals tended to fall into mere position habits.

The consideration of the sampling error of the two groups of the animals used in experiments I and II is found in the appendix.

CONCLUSIONS

1. The rat is able to discriminate the two maze patterns.

2. The rat prefers the pentagon to the equilateral triangle of equal length.[1]

3. *The daily-practice* method is far superior to the *free-learning method* for causing the discriminative preferences (rather than mere position habits) to appear.

[1] A further study in which pairs of still other maze patterns are offered for choice is under way in the same laboratory. In this study the possibility of a choice by mere position habits is further considered, and the factors involved in such habits are well controlled.

APPENDIX

SAMPLING ERROR

In these two experiments two groups consisting of 30 rats each were found to discriminate two maze patterns, and the evidence of discriminability of maze patterns and of the preference of one pattern to the other was based upon the significant differences of the group means as compared with choices based on mere chance. In order that any conclusion based upon such evidence may be valid, it is required that these two groups be similar samples. In other words, the individual scores of the first group must distribute themselves around the mean of the group in the same way as the individual scores of the second group distribute themselves around the mean of that group. If this requirement were not fulfilled, whatever group differences might be found could only be due to a particular performance of a particular sampling. In the case of our experiments, this requirement was met by the sigmas of distribution of the four series (table 1). In experiment I the composite sigma of the sigmas in series A and B is 8.91 ± 2.05; in experiment II the similar composite sigma is 11.50 ± 2.81. These two sigmas lie well within the standard error of each other. Hence these two groups can be considered similar as far as the running in this maze is concerned.

TABLE 1
The Mean Frequencies of the Choice of the Pentagonal Path

	Experiment I								Experiment II							
n=30	Series A (Free learning)				Series B (Daily practice)				Series B (Daily practice)				Series A (Free learning)			
	Mean	σx	σ	σ²	Mean	σx	σ	σ²	Mean	σx	σ	σ²	Mean	σx	σ	σ²
Choice of pentagonal path	37.70	1.45	7.94	1.01	39.13	1.4	10.65	1.90	41.03	2.67	11.33	1.46	36.57	2.11	11.56	1.49
Choice of the path by chance	30.00	3.87			30.00	3.87			30.00	3.87			30.00	3.87		
Difference between actual scores and probability	7.70				9.13				11.63				6.57			
Sigma difference	4.13				4.29				4.39				4.41			
Critical ratio	1.9				2.1				2.5				1.5			

$$\sigma x = \frac{\sigma}{\sqrt{n}}$$

$$\sigma \sigma = \frac{\sigma}{\sqrt{2n}}$$

$$\sigma p = \sqrt{npq}$$

$$\sigma \text{ diff.} = \sqrt{\sigma_1{}^2 - \sigma_2{}^2}$$

TABLE 2

Reliability Coefficients

n = 30		Experiment I		Experiment II	
		Series A	Series B	Series B	Series A
Half vs. half	$r_{(1, 2, 3, 4, 5)(6, 7, 8, 9, 10)}$	.127	.539	.648	.746
	Corrected by Brown's formula*	.225	.700	.788	.866
Odd vs. even, whole	$r_{(1, 3, 5, 7, 9)(2, 4, 6, 8, 10)}$	.331	.783	.902	.917
	Corrected by Brown's formula	.497	.878	.948	.957
Odd vs. even, first half	$r_{(1, 3, 5)(2, 4)}$	.840	.652	.804	.828
	Corrected by Brown's formula	.913	.789	.891	.906
Odd vs. even, last half	$r_{(7, 9)(6, 8, 10)}$	.669	.727	.795	.901
	Corrected by Brown's formula	.801	.842	.886	.948

* Brown's formula $r = \frac{2r}{1+r}$

TABLE 3

Inter-correlations

n = 30

Experiment I — Series A (Free-running)

Days	2	3	4	5	6	7	8	9	10	11
1	.74	.47	.53	.38	.15	.35	.28	.44	-.18	.31
2		.63	.35	.34	.48	.35	.14	.45	-.13	.13
3			.44	.43	.11	.14	.16	.15	-.13	.22
4				.61	.45	.37	.03	.11	.13	.13
5					.57	.58	.07	.12	-.24	.24
6						.56	.27	.14	.16	.17
7							.38	.30	.44	.44
8								.16	.32	

Series B (Daily practice)

Days	2	3	4	5	6	7	8	9	10	11
1	.49	.47	.47	.55	.51	.65	.14	.33	.36	
2		.55	.30	.26	.33	.45	.41	.32	.32	.29
3			.74	.41	.36	.23	.09	.38	.05	.05
4				.51	.40	.13	.03	.32	.10	.10
5					.21	0	.00	.14	.11	
6						.51	.33	.40	.36	.36
7							.70	.66	.36	
8								.60	.45	
9									.60	

Experiment II — Series B (Daily practice)

Days	2	3	4	5	6	7	8	9	10
1	.38	.64	.69	.11	.68	.65	.64	.13	.68
2		.60	.73	.58	.38	.41	.44	.17	.53
3			.60	.13	.36	.32	.63	.76	.55
4				.77	.33	.45	.73	.47	.54
5					.57	.59	.46	.48	.76
6						.69	.66	.45	.64
7							.73	.60	.74
8								.67	.80
9									.76

Series A (Free-running)

Days	2	3	4	5	6	7	8	9	10
1	.7	.64	.66	.72	.76	.66	.71	.40	.57
2		.60	.73	.56	.76	.63	.57	.51	.46
3			.60	.63	.70	.66	.44	.44	.45
4				.40	.62	.55	.54	.49	.48
5					.65	.59	.19	.15	.32
6						.77	.74	.78	.64
7							.71	.49	.53
8								.57	.46
9									.63

TABLE 4

Correlations between Series A and Series B

n = 30

	Experiment I	Experiment II
r(A, 1–10) / (B, 1–10)	.526	r'(B, 1–10) / (A, 1–10) .809
Corrected by Spearman's formula[1]	.796	.877
r(A, 1–5) / (B, 1–5)	.268	r'(B, 1–5) / (A, 1–5) .697
Corrected by Spearman's formula	.296	.772
r(A, 6–10) / (B, 6–10)	.626	r'(B, 6–10) / (A, 6–10) .625
Corrected by Spearman's formula	.762	.679

(1) $r = \dfrac{r_{xy}}{\sqrt{r_{x_1x_2}}\sqrt{r_{y_1y_2}}}$

LITERATURE CITED

BREED, F. S.

1912. "Reactions of Chicks to Optical Stimuli," *Jour. Animal Behavior*, 2: 280.

BINGHAM, H. C.

1913. "Size and Form Perception in *Gallus domesticus*," *Jour. Animal Behavior*, 3: 65.

CASTEEL, D. B.

1911. "The Discriminative Ability of the Painted Turtle," *Jour. Animal Behavior*, 1: 1.

COLE, L. J.

1907. "An Experimental Study of the Image Forming Powers of Various Types of Eyes," *Proc. Am. Acad. Arts and Sci.*, 13: 335.

COLE, L. W., and LONG, F. M.

1909. "Visual Discrimination in Raccoons," *Jour. Comp. Neur. and Psychol.*, 19: 657.

DE CAMP, J. E.

1920. "Relative Distance as a Factor in the White Rat's Selection of a Path," *Psychobiol.*, 2: 245.

HUNTER, W. S.

1913. "The Question of Form Perception," *Jour. Animal Behavior*, 3: 329.

KATZ, D., and REVESZ, G.

1908. "Experimentell psychologische Untersuchungen mit Hühnen," *Ztschr. f. Psychol.*, 50: 93.

KINNAMAN, A. J.

1902. "Mental Life of Two *Macacus rhesus* Monkeys in Captivity," *Am. Jour. Psychol.*, 13: 98.

LASHLEY, K. S.

1912. "Visual Discrimination of Size and Form in the Albino Rat," *Jour. Animal Behavior*, 2: 310.

ORBELLI, L. A.

1908. "Réflexes conditionnels du côté d'œil chez le chien," *Arch. d. Sci. Biol.*, 14: 1, 2.

PORTER, J. P.

1904. "A Preliminary Study of the Psychology of the English Sparrow," *Am. Jour. Psychol.*, 15: 331.

1906. "Further Study of the English Sparrow and Other Birds," *Am. Jour. Psychol.*, 17: 248.

Révész, G.
  1924. "Experiments in Animal Space Perception," *Brit. Jour. Psychol.*, 14: 387.

Watson, J. B.
  1907. "Kinaesthetic Sensations," *Psychol. Monog.*, No. 33.
  1914. *Behavior*, 363.

Waugh, K.
  1910. "The Rôle of Vision in the Mental Life of the Mouse," *Jour. Comp. Neur. and Psychol.*, 20: 549.

Yerkes, R. M.
  1907. *The Dancing Mouse.*

Yoshioka, J. G.
  1928. "Weber's Law in the Discrimination of Maze Distance by the White Rat." MS.

THE EFFECT OF CHANGE OF REWARD
ON THE MAZE PERFORMANCE OF RATS

BY

MERLE HUGH ELLIOTT

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—George M. Stratton, Warner Brown; and Edward C. Tolman, Editors. Price per volume, $3.50. Cited as Univ. Calif. Publ. Psychol.

THE EFFECT OF CHANGE OF REWARD ON THE MAZE PERFORMANCE OF RATS[1]

BY

MERLE HUGH ELLIOTT

PROBLEM

The purpose of this study was to determine the effect of changing to a new reward after rats had learned to run a maze for a certain reward. The animals were given daily trials in the maze and received a reward of bran mash at the end of each trial during the first nine days. On the tenth day and thereafter they received sunflower seed. The question was whether or not such a change would affect the maze performance of the animals.

LITERATURE

The literature on the use of incentives in animal learning has been classified by Simmons (1924, p. 2) as follows:

1. Experiments in which the incentive was considered only incidentally as a necessary means of controlling the training.

2. Experiments testing the relative effectiveness of different intensities of the same incentive.

3. Experiments testing the relative effectiveness of different incentives, or of a combination of incentives, compared with one alone.

This analysis would indicate that the greater number of the investigations in connection with animal "drives," "motives," or "incentives," have been largely concerned with purely technical problems. Such problems are important but it is questionable how far the solutions will be of any particular significance

for theoretical psychology. It seems that a fourth category should be added to those of Simmons. This would cover experiments specifically intended to study the strictly psychological problems of the nature of the "drives" and of their effect upon learning.

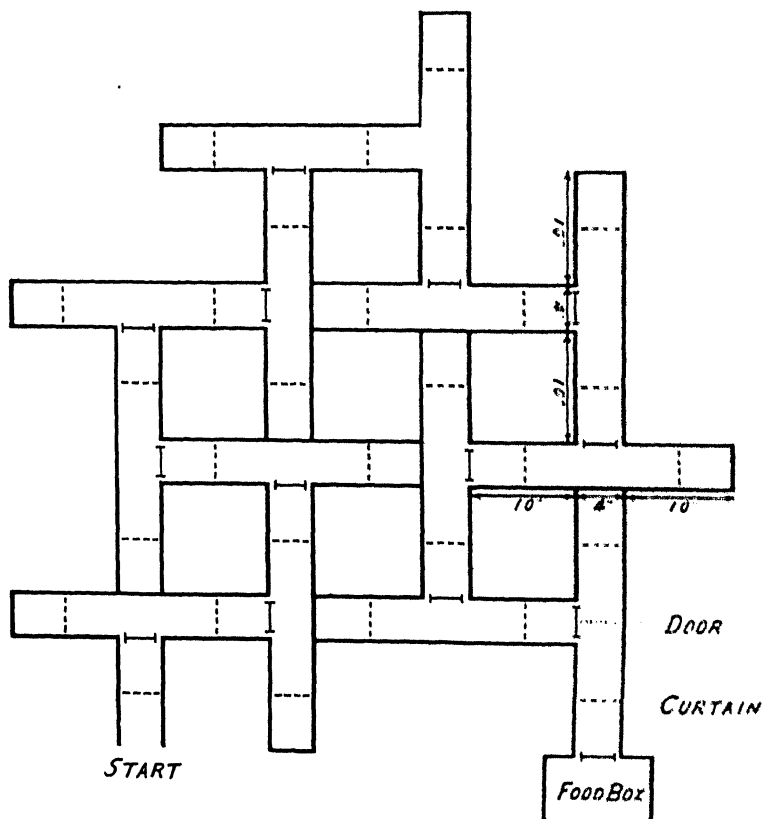Fig. 1. Plan of maze.

Let us consider now the investigations which bear upon this fourth type of problem. Szymanski (1918*a*) set out to answer the following very pertinent questions: After learning will the rat run the maze without the reward of food (p. 209)? Will some other drive serve as well (p. 211)? Szymanski's answers, however, are quite ambiguous and based on a very small number of animals.

Blodgett (1925) ran rats in a maze without reward for various periods (i.e., 3, 7, and 16 days), during which time they showed little improvement. A reward of food was then introduced and the animals almost at once showed a performance equalling that of the control groups which had been receiving food throughout the training. This indicates that "latent learning" had been taking place but was not being measured until the food reward was introduced. Szymanski (1918*b*, p. 376) and Simmons (1924, pp. 64–71) obtained similar results.

MATERIALS AND METHOD

The maze

The maze contained fourteen T shaped choice points arranged as shown in figure 1, each alley being four inches wide and ten inches long. Doors were closed behind the animals as soon as they had entered any particular alley, in order to prevent retracing. Curtains,[2] placed midway in each alley, made it impossible for the rats to utilize as a cue any constant visual difference between true path and cul de sac.

Animals

Untrained male rats ranging in age from sixty to ninety days, approximately, were used.

Method —

The rats were given one trial per day in the maze and were allowed to remain in the food box at the end for three minutes. They were then returned to the living cage and, about thirty minutes later, received the additional food necessary to make up an adequate daily ration. In this later feeding (except as noted in the case of the control group) the food was always of the same kind as had been received that day in the food box of the maze.

Records of both time and errors were made. Errors were counted when the rat entered a blind alley far enough to disturb

---

[2] The use of such curtains was first suggested by Dr. E. G. Wever. The curtains were made of heavy black cloth and they did not cause the rats any difficulty.

the cloth curtain. This is practically the same as the usual criterion of an entrance amounting to a body's length. Partial entrances were not recorded.

Controls—

The maze was uniformly lighted from above. Olfactory cues were very largely ruled out by frequent shifting of the curtains and by systematic brushing of the maze after each cage of rats (five or six) had been run.

PROCEDURE

Experimental group—

Twenty-five rats were trained in the maze, receiving a wet mixed food[3] for the first nine days. On the tenth and ensuing days sunflower seed, instead of the usual diet, was placed in the food box of the maze. Sunflower seed was also substituted in the later feeding in the living cages.

On the sixteenth day these rats of the experimental group were divided into two subgroups A and B, which were thereafter given differing treatment. The animals in A, from the sixteenth day on, were as usual allowed to eat sunflower seed at the end of their maze trial but they were given only a very small amount of food (also sunflower seed) at the later feeding time. The animals in B were returned to the original bran-mash regimen.

Control group—

In addition to the experimental animals a group of thirty were trained in the maze, always receiving sunflower seed as a reward. These animals usually received sunflower seed at the later feeding in the cages, but as a precautionary measure to keep them in condition for the whole training period, this was supplemented every fourth day by the standard mash diet.

---

[3] A modification of the Steenbock diet.

RESULTS

The rats of the experimental group showed the usual improvement in performance for the first ten days. Substitution of the sunflower seed on the tenth day, however, caused an increase in both time and error-scores on the eleventh and
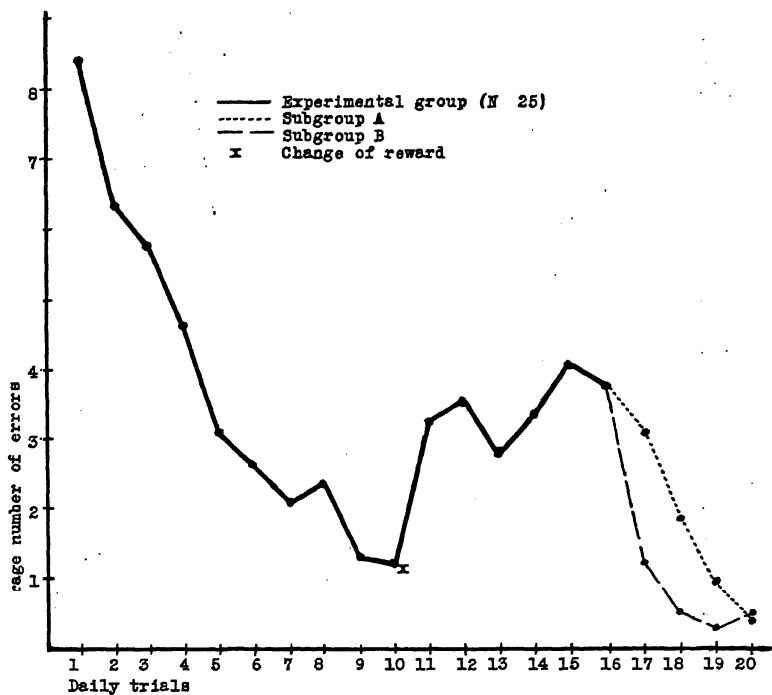
Fig. 2

succeeding days as shown in figures 2 and 3. The change in performance appears to be more than a mere temporary disturbance, since it increases rather than decreases during the course of six days. On the day of the change of reward, the tenth day, the animals did not eat steadily while in the food box but divided their time between eating and random searching.

During the period between the tenth and sixteenth day there was undoubtedly an increase in the number of partial entrances, which were not shown in the error scores. This would account in part for the large increase in the time scores.
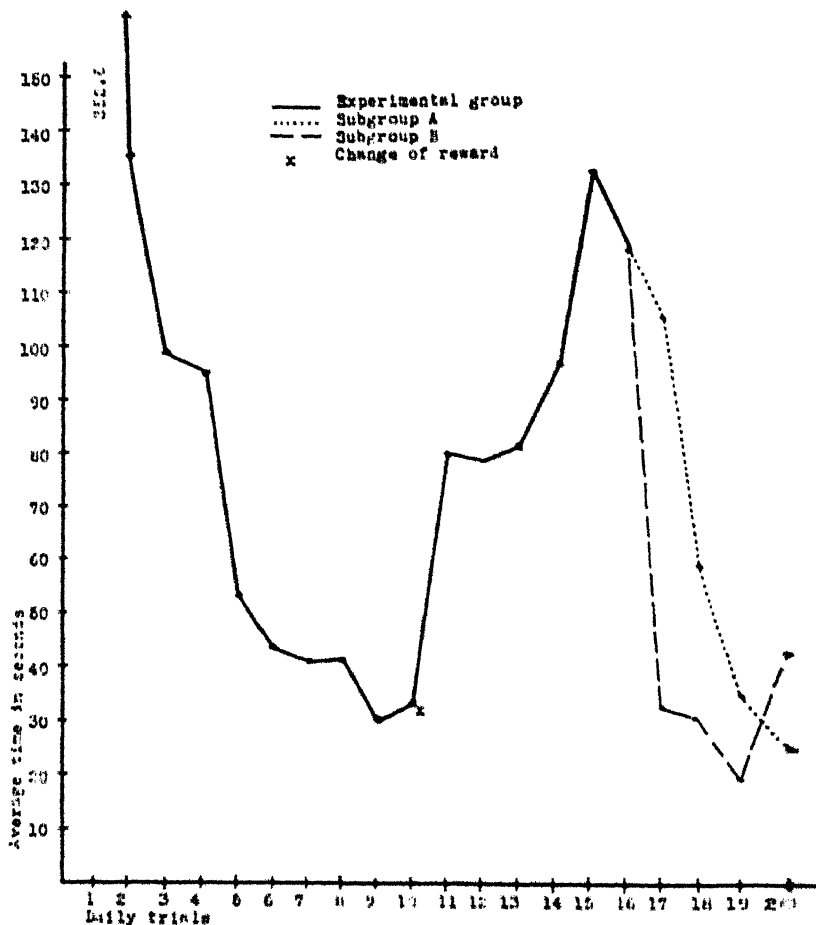
Fig. 3

Figures 2 and 3 depict, in terms of errors and time respectively, the differences in performance for the various stages of the training period. In order to show that the difference following the change to sunflower seed was significant, table I is

presented. This table gives the difference between the mean for the tenth day and that for each of the succeeding days, divided by the standard deviation of that difference (i.e., $\frac{diff}{\sigma_{diff}}$).[*] These ratios were computed from the data shown graphically in figures 2 and 3. Obviously these differences could hardly occur by chance.

TABLE 1

RELIABILITIES OF THE DIFFERENCES OF THE MEANS OF THE EXPERIMENTAL GROUP

Days	10–11	10–12	10–13	10–14	10–15	10–16
$\frac{diff}{\sigma_{diff}}$ (errors)	4.07	3.94	2.41	3.56	4.37	5.09
$\frac{diff}{\sigma_{diff}}$ (time)	2.95	2.94	2.59	3.47	4.64	4.63

The animals in subgroup A on a greatly decreased daily ration of sunflower seed (sixteenth to twentieth days inclusive) came back to their previous standard of performance or better.

Subgroup B, when again receiving the original wet mash diet, also returned to their previous standard. Inspection of the individual records suggests that this group as a whole returned more quickly and uniformly than the semi-starved animals, but the size of the groups is not sufficient to prove such a conclusion.

Figures 4 and 5 show the learning curves for both the experimental and the sunflower-seed groups in terms of errors and time, respectively. As may be seen, the learning of the latter

[*] The standard deviations (σ) for the *scores* on each day were computed by the formula: $\sigma = \sqrt{\frac{\Sigma F D^2}{N}}$. The standard deviations of the *means* for each day were then computed by the formula: $\sigma_m = \frac{\sigma}{\sqrt{N}}$. The standard deviations of the *differences of the means* for two days were computed by the formula: $\sigma_{diff} = \sqrt{(\sigma_{m1})^2 + (\sigma_{m2})^2}$. Differences of the means divided by the standard deviations of these differences are given in the table. In the comparisons between different performances of the same animals (table 1), slightly lower σ_{diff} and correspondingly *higher* ratios would be obtained by using the formula: $\sigma_{diff} = \sqrt{(\sigma_{m1})^2 + (\sigma_{m2})^2 - 2r\,\sigma_{m1}\sigma_{m2}}$. This would not hold, however, for the comparison between different groups of animals, as in table 2.

group was definitely inferior to that of the former. The results
would be more clear-cut and easier to interpret if the two learn-
ing curves were equal. Nevertheless, it is apparent that when
the reward of the experimental group was changed to sunflower
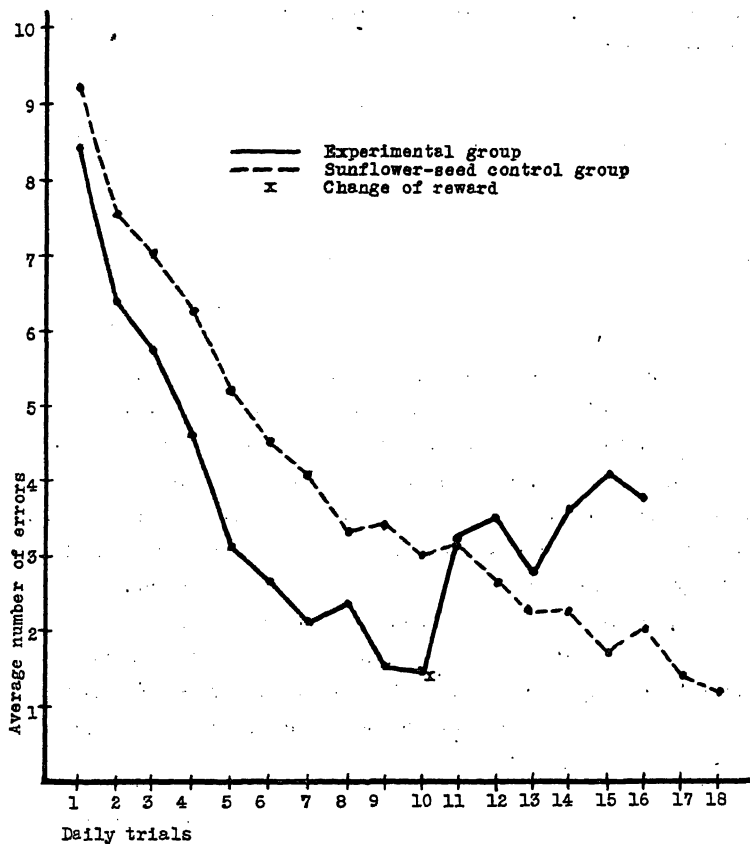
Fig. 4

seed the performance did more than merely rise to the level of
that of the control group for the corresponding period. Treating
the error- and time-scores in the way described for table 1, the
curves for the two groups were compared day by day for the
period from the eleventh to the sixteenth day. The ratios given

in table 2 show for each day the difference between the mean scores of the two groups (experimental compared with control) divided by the standard deviation of that difference ($\frac{diff}{\sigma_{diff}}$).
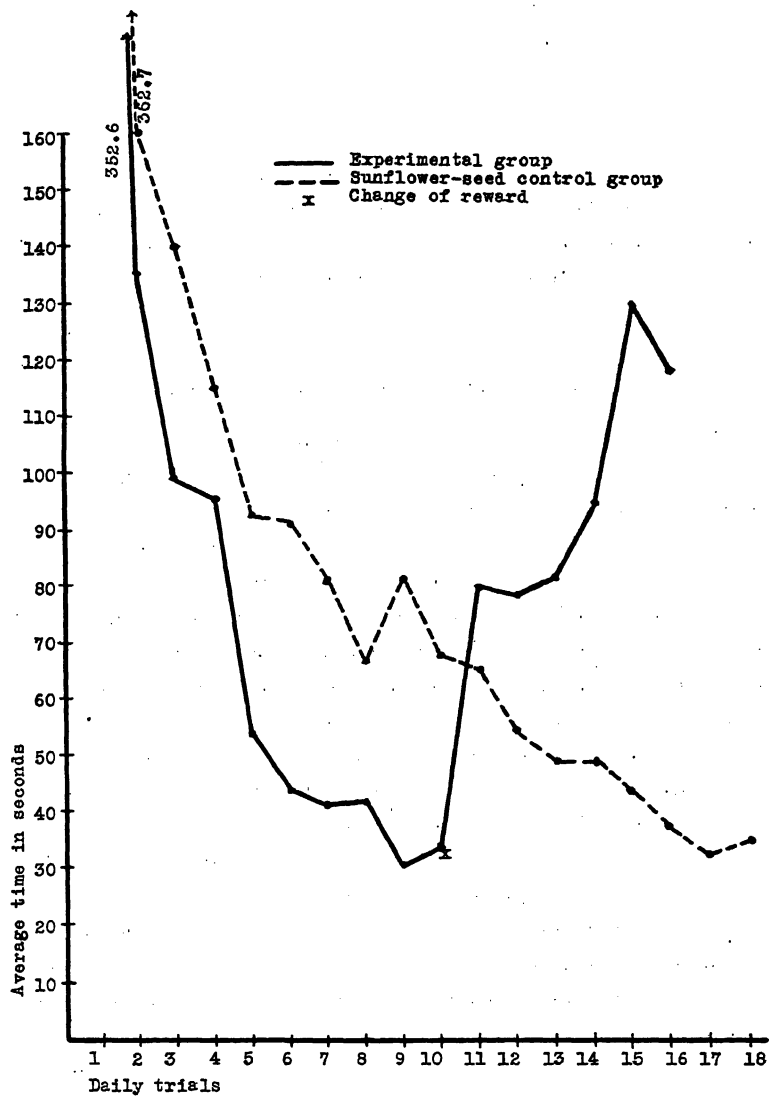
Fig. 5

TABLE 2

RELIABILITIES OF THE DIFFERENCES OF MEANS OF EXPERIMENTAL AND CONTROL GROUPS

Days		11	12	13	14	15	16
$\dfrac{diff}{\sigma_{diff}}$	(errors)	.07	1.48	.45	2.07	3.70	3.41
$\dfrac{}{\sigma_{diff}}$	(time)	.86	1.73	1.79	2.81	4.16	4.99

These ratios effectively bear out the impression given by the curves in figures 4 and 5. There is little difference between the two groups on the eleventh, twelfth, and thirteenth days, but thereafter the difference is definite and reliable.

DISCUSSION AND CONCLUSIONS

The difference in performance resulting from the change of reward might seem open to a number of different interpretations. Some of these possible interpretations will now be discussed.

In the first place it might be held that the difference is due to an emotional upset of some sort. However, we usually find a certain amount of habituation to an alarming situation, while in the present case the difference in performance *increased* over a period of six days. For this reason an emotional disturbance seems hardly an adequate explanation.

It is possible that the general physiological condition resulting from the sunflower-seed diet might be responsible for the change in performance. The evidence for this view is not strong, when we consider the control group. It will be remembered that on every fourth day they received a supplementary ration of the standard mash diet. According to the above hypothesis, we should expect an improved performance by these rats on the days following each bran feeding but no such improvement appeared.

A third interpretation would be that the increase in time and errors was due to a lessening of the hunger drive and hence is

comparable with the results obtained by Szymanski (1918*a*, p. 209) when he stopped rewarding rats which had been receiving food in the maze. The fact that the learning of the control group was inferior to that of the experimental gives evidence for this view. On the other hand the learning curve of the latter group rose distinctly *above* that of the control animals when the reward was changed. Moreover, computations[5] showed that after the change the experimental animals were receiving slightly less food in terms of calories as well as considerably less in actual volume. Presumably, then, they should have been fully as hungry as they were before the change of reward.

In view of the manner in which the animals actually behaved both in the maze and in the food box, preference is here given to a different and more prosaic interpretation. The animals made errors because they were searching for the accustomed (and more desirable) food; and, on the trials just preceding, the true path had not led to this goal. There was never any difficulty in getting the animals to traverse the maze, such as might have been expected from a weakened hunger drive. (Szymanski, 1918*b*, p. 375, found that satiated rats would not run the maze.)

The following conclusions are suggested:

1. Rats running the maze under the drive of hunger were learning to expect a specific reward rather than mere satisfaction of hunger.

2. The results obtained by Blodgett (1925) together with the present findings, indicate that performance in the maze may not exactly mirror the course of actual learning. A poor performance may be due to the strangeness or undesirability of the reward as well as to lack of learning.

---

[5] These computations were based on the data in various bulletins of the United States Department of Agriculture. The calory ratio was approximately 85:90. This ratio would be made still more significant if we had a measure of the relative amounts of food consumed in the food box of the maze during the three-minute period. The rats receiving sunflower seed were forced to spend a certain amount of time removing the shells, and besides, did not eat so steadily as those receiving bran.

3. In any experiment in which it is desired to show the true curve of learning, the reward must be kept constant and carefully standardized. This has not always been done.

LITERATURE CITED

BLODGETT, H. C.
    1925. ''The relation of reward to animal learning.'' Manuscript Ph.D. thesis, deposited in University of California Library.

SIMMONS, RIETTA.
    1924. ''The relative effectiveness of certain incentives in animal learning.'' *Comparative Psychology Monographs*, 2, no. 7.

SZYMANSKI, J. S.
    1918a. ''Abhandlungen zum Aufbau der Lehre von den Handlungen der Tiere.'' *Pflüger's Archiv für die gesamte Physiologie*, 170: 1–244.
    1918b. ''Versuche über die Wirkung der Faktoren, die als Antrieb zum Erlernen einer Handlung dienen können.'' *Pflüger's Archiv für die gesamte Physiologie*, 171: 374–385.

THE REWARD VALUE OF A
CONDITIONED STIMULUS

BY

KATHERINE ADAMS WILLIAMS

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—George M. Stratton, Warner Brown, and Edward C. Tolman, Editors. Price per volume, $3.50. Cited as Univ. Calif. Publ. Psychol.

THE REWARD VALUE OF A CONDITIONED STIMULUS[1]

BY

KATHERINE ADAMS WILLIAMS

PROBLEM AND METHOD

The experiment here described was designed to answer the specific question whether a box in which rats have been invariably fed becomes a reward in itself; that is, will such a box become a goal-object on its own account so that the animals will learn a maze in order to reach it even when it contains no food. According to one type of analysis,[2] the box, in this situation, becomes a conditioned stimulus to the food-seeking response. The present writer doubts the validity of this analysis; but let it be adopted for the present for the sake of convenience. The more general question may be formulated as follows: what is the reward value of a conditioned stimulus?

There are four main methods of comparing strengths of drive, and so, indirectly, of reward values. They are the obstruction method, the choice method, the learning method, and the latent learning method.

1. Moss made use of the obstruction method.[3] An animal is placed in a compartment the door of which leads across electric plates to another compartment in which there is food. The amount of current over which the animal will pass becomes a measure of the food drive.

[1] The experiment herein reported was carried out in the Psychological Laboratory of the University of California during the academic years 1926–27 and 1927–28. The author wishes to make grateful acknowledgment of her indebtedness to Professor Edward C. Tolman and Professor Warner Brown for their interest and advice.

[2] Watson, J. B., *Behaviorism* (1924), p. 25.

[3] Moss, F. A., "Study of Animal Drives," *Journal of Experimental Psychology*, 7 (1924): 165–185.

2. In the same study, Moss also employed the choice method. He placed an animal in the middle compartment of a three-compartment box. In the compartment on one side was a female in heat, in the compartment on the other was food. The number of times that one reward or the other was chosen was taken as a measure of the relative strength of drive.

3. Miss Simmons used scores made in learning a maze as a measure of drive.[4] The scores compared may be the total number of errors made before the maze is learned, total time consumed in learning, or number of trials required to learn.

Miss Simmons' method was at first favored for the present experiment for various reasons. In the first place, it is free from some of the weaknesses of the other two methods. The obstruction method involves a second drive and, from our point of view, the conditioning of an avoidance response; while the choice method does not offer a measurement which is statistically as clear and flexible as that afforded by the learning method. Furthermore, maze learning is itself a subject of great psychological interest, and it was hoped that some light might be thrown upon the process by which it takes place.

4. This learning method proper, however, proved to be unsuitable for our purpose,[5] and a modification of it was found in what may be called the latent learning method. The fact of latent learning was hinted at by experimental work done by Szymanski[6] and later by Simmons,[7] but was not examined thoroughly until Blodgett's experiment[8] clearly demonstrated its existence. Blodgett ran rats in a multiple-T maze. One group he fed after each trial for three minutes in the food box. The other group, like the

---

[4] Simmons, R., "The Relative Effectiveness of Certain Incentives in Animal Learning," *Psychological Monographs*, 2 (1924): no. 7.

[5] See Appendix A.

[6] Szymanski, J. S., "Versuche über die Wirkung der Faktoren die als Antrieb zum Erlernen einer Handlung dienen können," *Pflügers Archiv*, 170–171 (1918): 376.

[7] Simmons, R., "The Relative Effectiveness of Certain Incentives in Animal Learning," *Psychological Monographs*, 2 (1924): no. 7.

[8] Blodgett, H. C., "Relation of Reward to Animal Learning," unpublished Ph.D. thesis, deposited in the University of California Library, 1928.

first in every other respect, were given no reward at the end of the maze until the seventh day. Instead, they spent three minutes in the empty food box, after which they were returned to their living cages. All rats were given their daily food one hour after running the maze. Error curves for the two groups show that the non-reward group made little progress in learning before they were rewarded, but within two days after the introduction of the reward this group made as few errors as the groups which had been rewarded from the first day. Blodgett believes this indicates that during the non-reward period the rats did learn, but that this learning was held in a latent state and was manifested only after a reward was introduced. If this is so, it would seem that the extent to which the learning curve drops when a reward is introduced may be taken as a measure of the value of the reward.

In the present experiment the latent learning method was employed in the following manner. First, a group of rats were taught a discrimination habit. They were fed in the white side of a black-white discrimination box and in no other place. After conditioning, i.e., when they had learned to choose the white compartment, these rats were given one trial daily in an ordinary unpainted redwood maze. For the first eight days they found no reward at the end of the maze, and of course did not completely eliminate errors. On the ninth day, instead of introducing food as a reward, as in Blodgett's experiment, the experimenter placed the conditioned stimulus in the shape of the discrimination box *without food* at the end of the maze. The extent to which the learning curve dropped was taken as a measure of the reward value of the conditioned stimulus.

APPARATUS

The plan of the discrimination box is shown in figure 1. *A* is the starting box from which a door leads into the vestibule *B*. *C* and *D* are choice compartments leading out of this vestibule. *E* is the eating chamber. The whole box is made of red-

wood but *A* and *B* are unpainted and have green oilcloth on the floor. *C, D,* and *E,* on the other hand, are painted white on the inner sides and have white oilcloth on the floor. But in any given trial either *C* or *D* (*C* as shown in the figure) has fitted into it an inner shell in the form of a cardboard box open at one end only and lined with black oilcloth. This cardboad shell can easily be shifted from side to side—then sometimes (as in the figure) *C* is the white open side, and sometimes *D*. The animals thus develop no position-habits but have to learn to take the side which in that trial is white and open. The food dish is always placed around the corner out of sight from the entrance to the white compartment. The walls are 8 inches high. All other dimensions appear in figure 1.
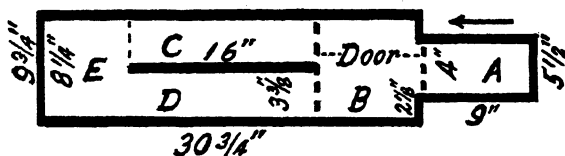
Fig. 1. Discrimination box.

The floor plan of the maze is shown in figure 2. It is a multiple-T maze of the same pattern as Stone's[9] except that it does not have the little T cross-bars at the ends of the blinds. The order of right and left turns is R L L R R L R R L R R L L R. The whole maze, including the starting box and the end box, is constructed of unpainted redwood, with walls 8 inches high. The other dimensions appear in the figure. Retracings from one alley to another are prevented by doors at the choice-points, indicated in the diagram by the dotted lines. (Dr. Blodgett pointed out the advantages of doors.) These doors are made of beaver board. They are hung at one upper corner and are opened by pulling strings attached at the diagonally opposite corner. They thus swing easily in the plane of the door. The experimenter sits at the point represented by *A* in the figure. From

9 Stone, C. P., and Nyswander, D. B., "Reliability of Rat Learning Scores from the Multiple-T Maze as determined by Four Different Methods," *Pedagogical Seminary,* 34 (1927) : 497–524.

this point the doors can be operated silently and all parts of the maze can be seen with the help of a convex mirror hung from the ceiling of the room.
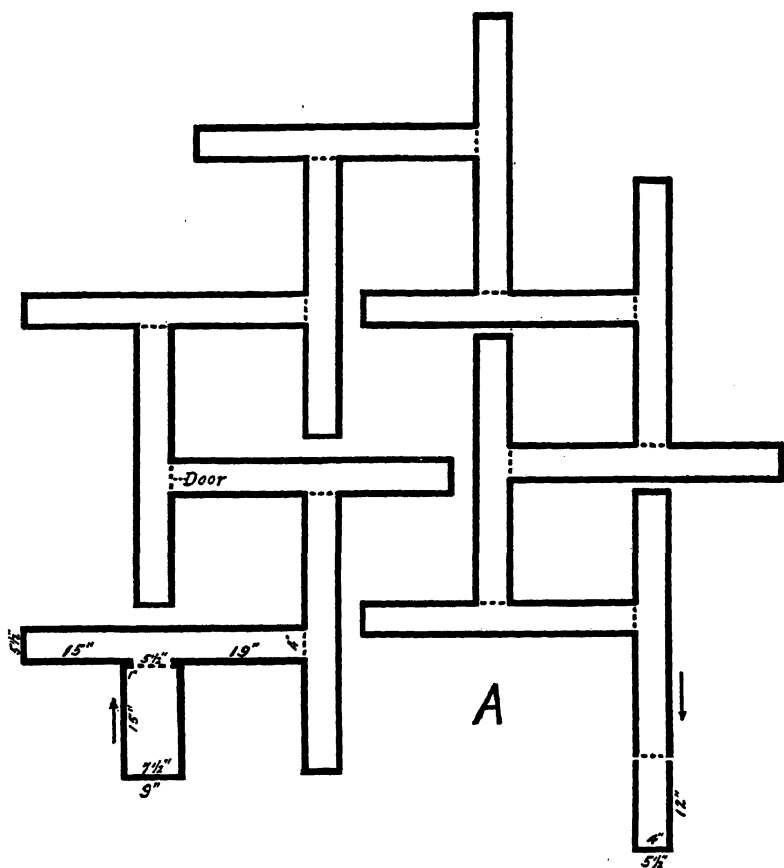
Fig. 2.   Maze.

Every alley has a separate floor covered with green oilcloth which can be removed and turned end for end or exchanged, to prevent the rats from trailing each other by smell.   As a further olfactory control, food dishes stand outside the starting box, the end box, and the eighth alley, so that the odor of food is pervasive and constant.

EXPERIMENTAL ANIMALS

The rats were females from the colony maintained by the Department of Psychology of the University of California. They were albino, with the exception of three which were pied. Of the latter, two were in Group II, and one was in Group III. All animals were between sixty and a hundred days old when the work was begun. There were 25 in each group.

PROCEDURE

The first part of the experiment consisted in "conditioning" the rats to the white compartment of the discrimination box. Since these animals had not been handled more than was necessary in caring for them in the colony, the first three days were spent in habituating them to the box and to handling. On the first day each rat was placed near the food in the discrimination box and allowed to eat for twenty minutes. (As a matter of fact very little food was consumed on these first days because the animals were very timid.) On the second day the animal was placed in the vestibule and allowed to find its way to the food. On the third day it was placed in the starting box and allowed to find its way to the food. After this amount of preliminary training, it was possible in the case of most animals to begin giving ten trials a day, but in a few cases the rat's timidity seemed to lead it to seek protection in the dark-covered compartment, where it would stay for an indefinite amount of time. In such cases, the choice was open to the experimenter of discarding these rats as useless, or coaxing them into the white side of the box by dragging the food dish a fraction of an inch ahead of them. She adopted the latter course and so succeeded at last in bringing every animal to the point where ten trials a day could be made.

Each trial consisted in placing the rat in the starting box and opening the door to allow it to enter the vestibule, where it made a choice between entering the black compartment and entering the white. If it entered the black compartment for the distance

of its body length, an error was recorded, but the rat was permitted to continue its explorations until it reached the food. It was allowed to eat for thirty seconds, and then was placed in the starting box, for another trial. Since the animal received its daily portion of food in this way, which involved a loss of time for the experimenter, it was desirable to feed it as little as would suffice to keep it in health. A few rats speedily adapted themselves to the experimental conditions and ate enough food in the thirty seconds allowed at the end of each of the ten trials. In many cases, however, the rats ate slowly and had to be given more time at the end of the tenth trial. Unsatisfactory as this method of controlling the amount of food consumed and the incentive of hunger manifestly is, it seemed to the experimenter better than allowing all rats to eat for the same length of time or than allowing them all to eat the same amount of food. All rats in this experiment lost weight, but, with the exception of three which died in the preliminary training period, they remained in good condition as shown by their speed; and the incentive was equal, so far as could be judged from the fact that they never had enough food to satisfy them.

The criterion of satisfactory conditioning was eight correct choices out of ten trials on each of three consecutive days; but if this criterion was reached before the twelfth day, the training was continued until that day. Thus, in the first part of the experiment the minimum number of trials given to any rat was 120. Many rats failed to meet the criterion within twelve days.

After the criterion had been met, it was assumed that the white compartment had become a conditioned stimulus to the food-seeking response and that its reward value might then be tested.

In addition to the experimental group proper, two control groups were needed. Up to this time no division had been made, all rats alike having been subjected to the process of conditioning just described. An effort was made to divide them now so that the three groups should be composed of rats possessing equally

good records on the discrimination box. It was often convenient, however, to assign rats to their groups before they had met the criterion of learning, and their performance after assignment sometimes proved to be better or worse than had been anticipated. In consequence, the group scores for the discrimination box are not exactly equal. However, since the correlation between box scores and maze scores is extremely low (in the case of Group II, .17; in the case of Group III, .09),[10] box scores cannot be taken as indices of ability to learn the maze, and therefore small differences between the groups in ability to learn the box may safely be ignored. An effort was also made to divide litters evenly among the three groups. At one period, however, 15 rats in the experimental group were being run alone and no rats from the litters used in this period are to be found in the other groups.

EXPERIMENTAL GROUP

(Group I)

For the first eight days these rats were given one trial a day in the maze without reward. When they finished running the maze they found only a plain unfamiliar end box. Here they were kept for thirty seconds, at the end of which they were returned to the living cage. Not less than two hours later, they received their daily portion of food by running ten times in the discrimination box.

On the ninth day the real test began. The conditioned stimulus—namely, the discrimination box, in every respect unaltered except that the food dish was empty—was introduced at the end of the maze. Since the conditioned stimulus was not reinforced for this one trial a day, various precautions were taken lest the response become weakened. In the first place these unreinforced trials were separated by an interval of twenty-four hours. Such an interval of rest in itself is usually sufficient in the case of the

---

[10] See Appendix B.

conditioned salivary reflex to restore the response.[11]   Also, the
ten customary trials in the box with food were given each day
two hours after the maze was run.   Finally, just before the rats
were put in the maze, they were tested each day in the discrimina-
tion box with reward to make sure that the response was in good
working order, and not until they had made three consecutive
correct choices were they put in the maze.

The conditions under which the rats found the discrimination
box at the end of the maze were made as similar as possible to
those in the regular discrimination trials.   The discrimination
box was, of course, in a different position in the room, since for
the regular discrimination trials it was on a low table, while for
the maze trials it was placed on the floor immediately end to end
with the end box of the maze.   The rat, however, was taken out of
the end box of the maze and put into the discrimination box by
hand, for it was thought that the handling might have become
part of the conditioned stimulus.   That is, the rat, having reached
the end box of the maze, was lifted into the starting box of the
discrimination box; the door of the latter was then opened and
the choice of the black or white alley was presented as usual.
With the discrimination box at the end of the maze, the rats of
this group were given fifteen trials, making, with the preceding
eight trials with only the plain end box of the maze, a total of
twenty-three trials.

<center>NON-REWARD CONTROL GROUP</center>

<center>(Group II)</center>

These rats had been through the same conditioning process as
those of Group I.   When they had met the criterion of learning
for the discrimination box, they were given one trial a day in the
maze without reward.   This was continued for fifteen days.   It
will be seen that Group II were treated throughout the fifteen
days just as Group I were treated for the first eight days.   After

[11] Pavlov, Ivan, *Conditioned Reflexes*, translation by G. V. Anrep;
Oxford University Press (1927), p. 58.

running the maze, they were kept for thirty seconds in the end box of the maze. They were then returned to their cages and were fed not less than two hours later, when they received food during their ten trials in the discrimination box.

REWARD CONTROL GROUP

(Group III)

Like all the others, these animals had been given the preliminary conditioning. Now they were given one trial a day in the maze, preceded by a test series in the discrimination box lasting until three consecutive correct choices were made. They ran the maze, finishing in the plain end box from which they were lifted into the discrimination box. Here they made their choice and received food. After eating for thirty seconds they were returned to their cages and not less than two hours afterward received their daily food in the discrimination box. It will be observed that they were treated throughout exactly as the rats of Group I were after the eighth day in the maze, except that they always actually obtained food in the discrimination box.

A criterion of error similar to that adopted for the discrimination box was adopted for the maze, an entrance of body length into a blind alley constituting an error. The time required to run the maze was taken with a stop-watch.

OUTLINE-SUMMARY OF THE PROCEDURE

A. Preliminary conditioning given to all groups.
> Ten trials a day in the discrimination box for 120 trials or until 8 out of 10 choices were made correctly for three consecutive days.

B. Experimental period.
> Group I. Experimental Group.
>> *a.* From the first to eighth day inclusive.
>>> 1. One trial a day in the maze *without reward* of any sort.
>>> 2. Not less than two hours after running the maze, ten trials in the discrimination box, when daily food was obtained.

b. From the ninth to twenty-third day inclusive.

 1. Trials in discrimination box with food until three consecutive correct choices were made, immediately followed by

 2. One trial in the maze *with the discrimination* box, without food, given at the end of the maze as reward.

 3. Not less than two hours after running the maze, ten trials in the discrimination box, when daily food was obtained.

Group II. Non-Reward Control Group.

 a. From the first to fifteenth day inclusive.

  1. One trial a day in the maze *without reward of any sort.*

  2. Not less than two hours after running the maze, ten trials in the discrimination box, when daily food was obtained.

Group III. Food Control Group.

 a. From the first to fifteenth day inclusive.

  1. Trials in the discrimination box with food until three consecutive correct choices were made, immediately followed by

  2. One trial in the maze *with the discrimination box, with food,* given as a reward at the end.

  3. Not less than two hours after running the maze, ten trials in the discrimination box, when daily food was obtained.

RESULTS

ERROR SCORES IN MAZE

The interest centers in the results obtained for the maze. Table 1 gives the mean number of errors for each day, with the sigma of the distribution and the sigma of the mean. Figure 3 is a graph of the means. It will be seen that Group III, the food control group, learns the maze in the usual fashion; Group II, the non-reward control group, improves a great deal, but reaches a level on the ninth day, after which no improvement occurs—a level above that of the food control group; Group I is similar to the non-reward group up to and including the ninth day, having, if anything, a somewhat higher average number of errors. On the ninth day, it will be remembered, the conditioned stimulus (the discrimination box) was introduced as a reward at the end of the maze. The result appears in the decreased number of errors from the eleventh day to the sixteenth. This improved

performance does not last, however, for errors begin to appear once more until on the last few trials the level of Group II is again reached.

How reliable are these differences between the groups? Table 2 shows the differences between the means of the three groups for successive days, and the critical ratios of these differences.
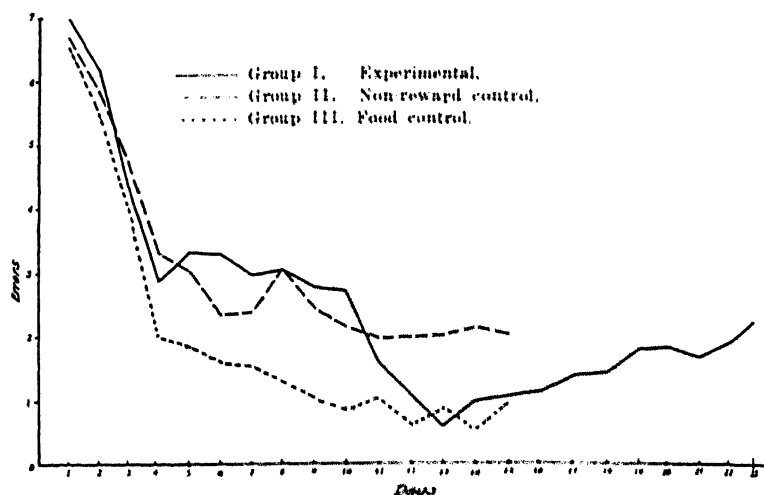
Fig. 3. Mean error scores in maze for successive days.

A comparison of Groups I and II reveals only insignificant differences for the first eleven days, but a difference as large as that found on the twelfth day would occur by chance only 52 times in 10,000. A similar comparison made for Groups I and III shows significant differences from the fourth until the eleventh day; that is, such differences would seldom occur by chance if no real difference existed. On the eleventh day the difference becomes much smaller, being obtainable by chance as often as 1,660 times in 10,000. On the thirteenth day Group I actually performs better than Group III. Differences as large as those found between Groups II and III after the fourth day would very seldom be found by chance.

In summary, we may say that up to the twelfth day Group I is not clearly different from Group II and is clearly different from Group III. For days 12, 13, 14, and 15, these relations are reversed: Group I is clearly different from Group II and is not different from Group III.

The same results are shown more plainly by composite scores based on the total number of errors for the four days which precede the introduction of the reward, i.e., days 6, 7, 8, and 9, as compared with scores based on the total number of errors made on days 12, 13, 14, and 15. These scores follow.

TOTAL NUMBER OF ERRORS PER RAT FOR DAYS 6, 7, 8, AND 9

	Mean	σ	σ_m
Group I	11.84	5.43	1.09
Group II	10.04	5.69	1.14
Group III	5.40	3.75	.75

MEANS OF GROUPS COMPARED

	Difference	σ difference	C. R.
Group I *minus* Group II	1.80	1.58	1.13
Group I *minus* Group III	6.44	1.32	4.88
Group II *minus* Group III	4.64	1.37	3.39

If no real differences existed, a difference as large as that found between Groups I and II would occur by chance 1,282 times in 10,000, and one as large as that between I and III would occur by chance only .034 times in 10,000.

Now let us look at the comparable scores for days 12, 13, 14, and 15.

TOTAL NUMBER OF ERRORS PER RAT MADE ON DAYS 12, 13, 14, AND 15

	Mean	σ	σ_m
Group I	3.60	3.21	.64
Group II	8.08	6.63	1.33
Group III	2.96	2.65	.53

MEANS OF GROUPS COMPARED

	Difference	σ difference	C. R.
Group II *minus* Group I	4.48	1.47	3.05
Group I *minus* Group III	.64	.83	.77
Group II *minus* Group III	5.12	.143	3.59

If no real difference existed between these groups, a difference as large as that found between Groups I and II would occur by chance 12 times in 10,000; and one as large as that between Groups I and III, 2,206 times in 10,000.

From these data it is plain that in the period during which no reward was given, Group I is not significantly different from the non-reward control, but that after the conditioned stimulus is introduced it becomes significantly different from the non-reward group and indistinguishable from the food group.

Furthermore, analysis shows that the drop in the scores of Group I for days 12, 13, 14, and 15 as compared with days 6, 7, 8, and 9 is significantly greater than the drop in the same period for Group II.

DROP IN SCORES FOR DAYS 12, 13, 14, AND 15, AS COMPARED WITH
DAYS 6, 7, 8, AND 9

	Mean	σ	σ_m
Group I	8.24	5.89	1.18
Group II	2.00	7.36	1.47

MEANS COMPARED

	Difference	σ difference	C. R.
Group I *minus* Group II	6.24	1.88	3.32

In terms of probability, this means that a drop as great as that found in Group I could occur by chance in Group II only 4.8 times in 10,000.

We have seen that the drop in the learning curve of Group I is a significant drop. We may now ask whether the subsequent rise is a significant rise. If we compare the total number of errors which Group I makes on days 20, 21, 22, and 23 with the total number of errors which it makes on days 12, 13, 14, and 15, we shall have an answer to this question.

NUMBER OF ERRORS MADE BY GROUP I ON DAYS 20, 21, 22, AND 23

	Mean	σ	σ_m
Group I	7.60	4.99	.999

MEANS COMPARED

	Difference	σ difference	C. R.
Group I on days 20, 21, 22, and 23, *minus* Group I on days 12, 13, 14, and 15	4.00	1.14	3.52

Group I would change this much by chance 2.3 times in 10,000. If the sigma of the difference between the records of Group I at the two different times be corrected on the basis of the correlation of these two records (.79) by the formula

$$\sigma \text{ Diff.} = \sqrt{\sigma_{Mx}^2 + \sigma_{My}^2 - 2R_{xy}\, \sigma_{Mx}\, \sigma_{My}},$$

it decreases to .60. This makes the critical ratio 6.66, and the probability that such an increase in number of errors would occur by chance is considerably less than .003 in 10,000.

TIME SCORES IN THE MAZE

Time scores are probably ambiguous[12] but it was thought worth while to calculate averages (table 3) and to plot a curve (fig. 4) for the successive days. These tell the same story as the record of errors. Group I and II are much alike until the introduction of the reward, when I diverges from II and becomes like III for a few days. It does not maintain its record at the level of Group III, however, but tends to rise again to its own old level.

Let us analyze the composite time scores for days 12, 13, 14, and 15.

TOTAL TIME PER RAT FOR DAYS 12, 13, 14, AND 15

	Mean	σ	σm
Group I	125.24	53.80	10.76
Group II	301.60	372.92	74.58
Group III	128.84	57.70	11.54

MEANS OF GROUPS COMPARED

	Difference	σ difference	C. R.
Group II *minus* Group I	176.36	75.34	2.34
Group I *minus* Group III	3.60	15.77	.23
Group II *minus* Group III	172.76	75.46	2.29

---

[12] Tolman, E. C., and Nyswander, D. B., "The Reliability and Validity of Maze Measures for Rats," *Journal of Comparative Psychology*, 5 (1925): 407–415.

A difference as large as that found between Groups I and II would occur by chance, if no real difference existed, 96 out of 10,000 times.   Group I is better than Group III, although unreliably so, since a difference as great as this would occur 4,090 times in 10,000 by chance.   It is noticeable that the sigmas vary far more than the means.   The sigma of the non-reward group is five or six times that of either of the other two.
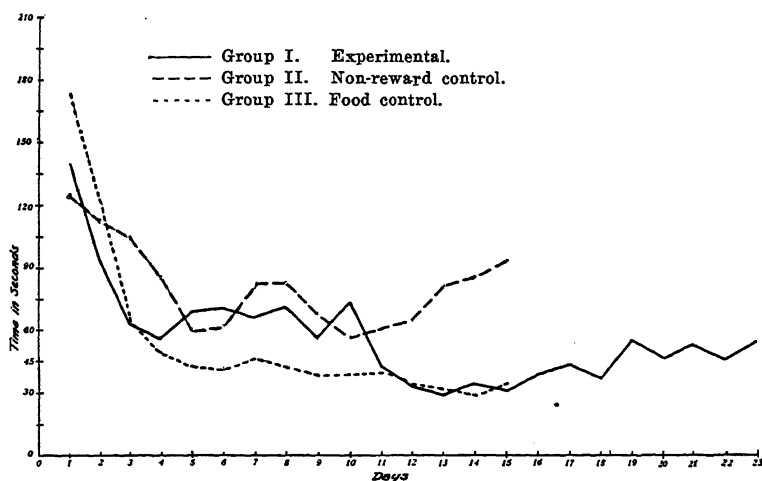
Fig. 4.   Mean time scores for successive days.

SUPPLEMENTARY RECORDS OF SCORES MADE ON THE DISCRIMINATION BOX

In order to interpret these results it is desirable to know how the groups compare with one another in the number of errors made in the discrimination box in the ten daily trials for the period during which the maze was being run.   We find no significant differences.   The critical ratios of such differences as occurred in the total number of errors made, and the number of times in 10,000 that such differences would be obtained by chance, if no real differences existed, follow:

	C. R.	Probability
Group I *minus* Group II.............................	.34	3669
Group I *minus* Group III............................	.66	2546
Group II *minus* Group III.........................	.33	3707

Table 4 shows the average number of errors made in the test series in the discrimination box immediately before running the maze. Here Group I appears, if anything, slightly superior to Group III. Since this difference can easily be explained by the fact that Group I has had nine more days of training in the discrimination box, it seems unnecessary to discuss its significance.

Table 5 shows the total number of errors made by Groups I and III in the box when it was entered at the end of the maze. Sigmas were calculated by the formula, $\sigma = \sqrt{N\ P\ Q}$.[13] With the use of these sigmas, critical ratios of the existing differences were found. These appear with their interpretation in terms of probability in the table. The differences found for the first few days might easily occur by chance. However, they increase until such differences as those found for the last few days would almost never occur by chance. Group III has eliminated all errors, while Group I makes more than in the first trials.

These three series of scores show that there was no general breakdown of the discrimination habit even in Group I, which found no food in the box at the end of the maze. The habit was weakened only when the box was in this specific setting, and not in the daily trials in the box by itself, when food was obtained.

CONCLUSION

The assumption of this experiment was that when the rat, in the discrimination trials in the box alone, had learned to take the white path to food, a part of the situation, afforded presumably by the white compartment, had become a "conditioned stimulus." The principal question was: Has a "conditioned stimulus," thus

[13] Yule, C. U., *An Introduction to the Theory of Statistics* (1922), pp. 254 ff.

defined, also the reward value of food? The principal results indicate that it has this value. That is, the animal will learn to traverse a maze for the sake of the white compartment alone, with an alacrity as great as that evinced for the sake of food itself. On the other hand, the conditioned stimulus rapidly loses this reward value when, in the problem-situation, there is no reinforcement by the unconditioned stimulus, i.e., when the white compartment is regularly found empty at the end of the maze. Now, the supplementary figures adduced in the last section contribute to the demonstration by indicating that the loss of reward value is, in turn, concurrent with the loss of just that character which originally identified our "conditioned stimulus." That is, those animals which ceased to run the maze efficiently for the sake of the (empty) white compartment, ceased concomitantly to make, in the box, when they had reached it through the maze, the reaction appropriate to the white compartment as representative of food. Finally, however, we find that this result does not mean a failure of discrimination, but the achievement of a new discrimination. This is shown by the fact that the very rats which had repeatedly found the box empty at the maze-end, and had finally learned not to exert themselves to reach it, and not to treat it as a veritable food box when it was reached, indicated by their continued infallibility in the daily discrimination trials in the box alone, with food but without the maze, that the box in the one situation is to them a different thing from the box in the other situation.

1. The conditioned stimulus has, for a time, a reward value equal to that of the (unconditioned) stimulus itself.

2. It very soon loses this value in a given setting, if it is not reinforced by the unconditioned stimulus.

3. Its loss of reward value, however, is concomitant with a loss of, or change in, its character as a conditioned stimulus.

APPENDIX A

In a preliminary experiment the learning method of measuring drives was employed. Fifteen rats, conditioned exactly as were those in the main experiment, were run in the maze, receiving the conditioned stimulus as a reward from the first day. The number of rats was too small to give reliable results, but there is no indication that any real differences exist between these rats and the non-reward control group. At no day or group of days does the group of rats which had the conditioned stimulus as reward surpass the non-reward group significantly.

These results are regarded as corroborative of the results obtained in the main experiment rather than as contradictory. There is no improvement as compared with the non-reward group because concurrently with the learning of the maze, the box at the end of the maze, and empty, has become distinguished from the box by itself, and when containing food.

APPENDIX B

An interesting by-product of this experiment is the correlation between the scores made in the discrimination box and those made in the maze. Calculations were made only for Groups II and III, since for Group I conditions did not remain constant throughout the experimental period. These two groups were run for different rewards, so the calculations are made for each separately.

First it was necessary to know the reliabilities of the box and of the maze. The reliability of the box was found by correlating the scores made on odd-numbered days with those made on even-numbered days, including days 3 to 26. The reliability for each of the two groups was the same, i.e., $.93 + .027$ (corrected by the Brown-Spearman formula, .96).

The reliability for the maze was computed by correlating scores made on odd-numbered days with those made on even-numbered days, including days 2 to 15. The same coefficient of correlation, i.e., .79 + .075 (corrected by the Brown-Spearman formula, .88), was again found for each group.

The correlation between the box and the maze was found by correlating the total number of errors made in the box between days 3 to 26 inclusive, with the total number of errors made in the maze between days 2 to 15 inclusive. In the case of Group II the correlation was .16 + .19. When this was corrected for attenuation it became .17. The correlation for Group III was .08 + .20. When corrected it was .09.

In other words, *practically no correlation was obtained between discrimination box and maze in spite of the fact that each in itself seems to have been a very reliable instrument.*

TABLE 1

ERROR SCORES FOR SUCCESSIVE DAYS

Days	Group I		
	Mean	σ	σ_m
1	6.96	1.78	.36
2	6.16	1.66	.33
3	4.36	2.06	.41
4	2.84	1.64	.33
5	3.28	1.66	.33
6	3.24	2.39	.48
7	2.92	1.96	.39
8	3.00	1.94	.39
9	2.72	1.95	.39
10	2.68	2.22	.44
11	1.56	2.77	.55
12	1.04	1.11	.22
13	.56	.70	.14
14	.96	1.56	.31
15	1.04	1.17	.23
16	1.12	1.03	.21
17	1.36	2.02	.44
18	1.40	1.50	.30
19	1.76	1.90	.38
20	1.80	1.88	.38
21	1.64	1.65	.33
22	1.88	1.63	.33
23	2.24	1.79	.36

Days	Group II			Group III		
	Mean	σ	σ_m	Mean	σ	σ_m
1	6.68	1.54	.31	6.52	1.53	.31
2	5.84	2.00	.40	5.48	2.06	.41
3	4.72	2.13	.43	4.00	1.98	.40
4	3.28	1.70	.34	2.00	1.80	.36
5	3.00	2.17	.43	1.88	1.98	.40
6	2.32	1.91	.38	1.60	1.30	.26
7	.36	1.65	.33	1.52	1.60	.32
8	3.00	2.43	.49	1.28	1.15	.23
9	2.40	2.32	.46	1.00	1.02	.20
10	2.12	1.53	.31	.84	.92	.18
11	1.96	1.48	.30	1.00	.89	.18
12	1.96	1.43	.29	.60	.85	.17
13	2.00	2.33	.47	.88	1.03	.21
14	2.12	1.56	.31	.52	.81	.16
15	2.00	2.35	.47	.96	1.56	.31

TABLE 2

DIFFERENCES BETWEEN MEANS FOR SUCCESSIVE DAYS, WITH CRITICAL RATIOS

Days	Group II-I		Group I-III		Group II-III	
	Difference	C. R.	Difference	C. R.	Difference	C. R.
1	.28	.59	.44	92	.16	.36
2	.32	.62	68	1 28	36	.63
3	− .36	.61	36	63	72	1.22
4	− .44	.94	.84	1 71	1 28	2.61
5	− .28	.52	1 40	2 69	1 12	1.90
6	− .92	1.51	1 64	2 98	72	1.59
7	− .56	1.10	1 40	2 80	84	1.83
8	0.00	0.00	1 72	3 19	1 72	3.19
9	− .32	.53	1 72	3 91	1 40	2.80
10	− .56	1.04	1.84	3 83	1 28	3.67
11	.40	.64	.56	97	96	2.74
12	.92	2.56	.44	1 57	1 36	4.00
13	1.44	2.94	.32	1 24	1 12	2.20
14	1.06	2.50	.44	1 33	1 60	4.85
15	.96	1.85	.08	20	1 04	2.21

TABLE 3

MEAN TIME SCORES ON MAZE FOR SUCCESSIVE DAYS

Days	Group I, Time in seconds	Group II, Time in seconds	Group III, Time in seconds
1	139.32	124.28	173.24
2	95.24	111.72	122.00
3	62.52	104.04	64.12
4	56.32	84.44	48.80
5	67.92	59.80	43.28
6	70.40	61.12	40.80
7	65.36	81.24	45.84
8	70.56	80.68	42.32
9	56.68	67.16	37.08
10	73.20	56.52	38.92
11	41.16	66.08	39.72
12	32.20	64.44	33.96
13	28.84	80.88	31.60
14	33.60	84.52	28.88
15	30.80	92.48	34.20
16	37.96		
17	44.04		
18	36.56		
19	55.80		
20	46.60		
21	53.20		
22	45.40		
23	54.36		

TABLE 4

AVERAGE NUMBER OF ERRORS MADE IN BOX IN TRIALS IMMEDIATELY
PRECEDING MAZE RUNNING

Days	Group I	Group III
1	.24	65
2	.28	.55
3	.24	35
4	52	25
5	.16	.20
6	20	24
7	.24	45
8	16	.20
9	0 00	20
10	.04	.40
11	.40	55
12	0 00	25
13	16	15
14	04	15
15	08	25

TABLE 5

TOTAL NUMBER OF ERRORS MADE IN BOX AT END OF MAZE

Days	Group I	Group III	C. R.	Probabilities of finding such differences by chance
1	8	5	.98	1635 in 10,000
2	4	5	.37	3557
3	6	2	1.58	570
4	4	0	2.16	154
5	5	0	2.50	62
6	3	1	1.05	1469
7	5	1	1.70	367
8	5	0	2.50	62
9	8	2	2.22	132
10	6	1	2.13	166
11	7	1	2.45	71
12	11	0	4.40	.034 --
13	9	0	2.92	17
14	7	0	3.11	9
15	11	0	4.40	.034 --

AN EXPERIMENTAL STUDY OF THE RAT'S "INSIGHT" WITHIN A SPATIAL COMPLEX

BY

HSIAO HUNG HSIAO

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—George M. Stratton, Warner Brown, and Edward C. Tolman, Editors. Price per volume, $3.50. Cited as Univ. Calif. Publ. Psychol.

AN EXPERIMENTAL STUDY OF THE RAT'S "INSIGHT" WITHIN A SPATIAL COMPLEX[1]

BY

HSIAO HUNG HSIAO

The concept "Einsicht" (translatable into English as insight or intelligence) has been applied by W. Köhler (1927) to the animal's act or ability of grasping "a material, inner relation of two things to each other." Since the publication of his experiments on chimpanzees, a number of studies have been made in connection with the problem of insight-learning. These have been well summarized by E. C. Tolman (1927) up to the end of the year 1927.

In very few of these studies have rats been used as subjects, and those that have been concerned with the "insight" of rats have yielded conflicting results.

GENERAL PROCEDURE

The apparatus used in this investigation was a special type of maze, the ground-plan of which is shown in figure 1. E_I and E_{II} represent alternative entrances. When the starting-box was placed at E_I, E_{II} was closed, and when it was placed at E_{II}, E_I was closed.

D_1, D_2, D_3, D'_3, F_3, and F_c are doors made of wire mesh. They hang from the top and swing only in the directions indicated by the small arrows. They are manipulated by the rat itself.

The maze presents three alternative routes to food (irrespective of whether the entrance is at E_I or E_{II}). The *first route,*

[1] This work was done in the Psychological Laboratory of the University of California. The writer is indebted to Professor E. C. Tolman for both the problem and the general principle of the maze, and for his encouragement, owing to which the details of the maze and the principles of the procedure have been worked out.

R_1, starts from the entrance (either E_I or E_{II}) and thence goes via D_1 and F_c to food. The *second route*, R_2, starts from the entrance and thence goes via D_2 and F_c to food. The *third route*, R_3, starts from the entrance and goes via D_3, D'_3, and F_3 to food.

It will be noted that routes R_1 and R_2 converge into a *final common path*, viz., a part of the section between D_1 and D_2, and the common door F, leading from this section into the food compartment. *The purpose of the experiment was to discover whether or not the rat could acquire insight into the fact of*
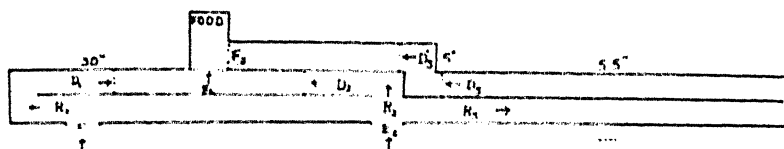
Fig. 1

this final common path so that, if this final path should be made "bad" by the locking of F_c, the rat, having reached it by R_1 and returning out of R_1, would not then attempt to go to food by R_2 (although he had previously built up a very strong propensity to choose R_2).

The general procedure adopted for testing for such insight may be outlined as follows:

1. Each rat was first given a brief preliminary exercise in learning to manipulate doors of the type of D_1, D_2, D_3, D'_3, F_3, and F_c, in a simple "straight-away" containing three such doors. (This "straight-away," having its own starting- and food-boxes, lay alongside the maze proper. It is not shown in the figure.)

2. Each rat was then subjected to a series of *training trials* in the maze proper.

　　a. On any given training trial two of the three doors D_1, D_2, and D_3 were locked and the other one was left unlocked. In this way, the rat was forced *in that trial* to take (sooner or later) that one of the three routes corresponding to the unlocked door.

b. In general, the attempt was made to give, in this way, greater training on both R_1 and R_2 than on R_3, in order to build up a strong propensity for both R_1 and R_2 and only a weak one for R_3.

c. During these training trials the subsequent choices made by the rat *upon retracing out of R_1 or R_2 or R_3* were recorded. In this way it was possible to observe and measure the extent to which, during the training trials, the rat had built up propensities, upon retracing, to go into R_1 or R_2 or R_3.

d. The arrangements and frequencies of training trials on the three routes were varied until an arrangement was finally found which (with the entrance of E_0) gave, when the animals retraced out of R_1 (because they had found D_1 closed), a large proportion of cases in which they turned into R_2, and chose R_3 only as a last resort.

3. Finally, each rat was given a series of *test trials.*

a. In these test trials all three doors D_1 and D_2 and D_3 were unlocked.

b. In addition, door D_1 was made to swing both ways so that if the rat got into the final common section of R_1 and R_2 (and found F_c locked) he could retrace out again through D_1.

c. Finally, most important of all, door F_c was locked.

The purpose of these test trials, as was said, was to see if the rats, after taking R_1 for which, as a result of the training trials, they had acquired a strong propensity, and finding it locked, would then, on retracing out through D_1 and thence back to the starting point, *show insight into the "common badness" of the final portions of R_2 and of R_1, so that, instead of attempting to go into R_2, they would now go directly to R_3.*

PART I

In the beginning of the training series the entrance was at
E_I, so that R_2 was the shortest path, R_1 the next shortest, and R_3
the longest; and the original expectation was that the animals
would in the training series build up the strongest propensity
for R_2, the next strongest for R_1, and the weakest for R_3. It
was expected that, in the final test, they would first enter R_2,
but, finding F_c locked, would retrace out of R_2, and then, if they
had no insight, turn next into R_1, but, if they had insight, go
directly to R_3. The training was originally arranged with this
in mind, and it was as follows: *first*, 42 consecutive trials on R_1
(i.e., D_1 and F_c unlocked, D_2 and D_3 locked); *second*, 17 con-
secutive trials on R_2 (D_2 and F_c unlocked, D_1 and D_3 locked);
third, 16 consecutive trials on R_3 (D_1 and D_2 locked, but D_3, D'_3
and F_3 unlocked).

After this amount of training, an analysis was made of the
results in order to see what propensities were actually appearing.
The results of this analysis are shown in tables 1, 2, and 3. The
data are arranged in these tables so as to indicate which way the
animals tended to turn when retracing out of R_2 and when
retracing out of R_1. It appears from the tables that, in coming
out of R_2, they showed a slightly stronger tendency to go to
R_3 than to R_1. It was felt that, under these conditions, the final
test would not be crucial, for the propensity to go to R_1 was not
strong enough to make sure that, if in the test they failed to
take R_1, it was because of real insight.

A change in the training procedure was therefore made. The
entrance to the maze was shifted from E_I to E_{II}. Thus R_1 was
made the shortest path and R_2 the next shortest. Now it was
expected that the strongest propensity would be for R_1, the
next strongest for R_2, and the weakest again for R_3. Under
such conditions, the test of insight would be to see whether the
animals, in retracing out of R_1 after finding F_c locked, would
go directly to R_3, without bothering to try R_2. In order, how-

ever, for such behavior in the *test* to give definite evidence of
insight, it would be necessary to show that in the *training,*
when it was D_1 and not F_c that was locked, the animals had
shown a strong propensity, upon retracing out of R_1, *to try R_2.*
Tables 1, 2, and 3 already show some tendency of this latter
sort. It is to be noted, however, that, during the period of
training on R_3 (table 2), this tendency was somewhat concealed
by the fact that they were trained on R_3 before learning R_2,
and therefore would be less likely to go to the place where food
had never as yet been found. This is clearly shown in table 4
by the enormous difference in frequency between the entrances
into R_2 during the first two days of training on R_3 and those
during the following fifteen days.

During the period of training with entrance at E_{II}, each of
the three routes was opened by turns, and rats were trained
according to a predetermined series, in which R_1 and R_2 were
opened twice and R_3 was opened once. One series of training
was given on each day, and this was done for three successive
days. The results of this training are given in table 5. There
was now a very strong propensity upon coming out of R_1 to
take R_2.

On the third day, immediately after the training period,
three tests for insight were given. During the tests, F_c was
fastened shut, and D_1 was made openable in both directions;
but the doors for the other two routes remained in the same
condition as before.

The results of these tests may be stated as follows: In the
first test, rats I and V went directly from R_1 to R_3; IV, after
coming out of D_1, stopped for a while at the opening of R_2; II,
III, VI, and VII actually entered D_2 after coming out of D_1,
but finding F_c locked, made the circuit out through D_1 again
and then went directly to R_3. In the second test, rats I and VI
went directly from D_1 to R_3; rat V entered R_2 directly from the
entrance, and made the circuit from D_1 to R_3; and the rest
behaved in the same way as the majority did in the first test.
In the third test, rats I and II peeped at D_2 when coming out

of D_1, and then went their way to the food box; rat III, coming out of D_1, stopped for a while at the opening of R_2 before proceeding to its destination; and all the rest went directly from D_1 to R_3.

These findings suggest the existence of something like insight as to the uselessness of R_2 when F_c is closed. However, it seemed possible that the results might be due to chance.

It occurred to the writer that a greater amount of alternate training on the three routes, or an increase of the distance between D_1 and D_2, or an improvement of some other conditions, or all these things combined might increase such insight as might exist and consequently enhance the certainty with which the results could be interpreted.

PART II

Therefore, for the purpose of testing the findings, another experiment with three new rats (1, 2, and 3 respectively) was undertaken. In this experiment the only change that was made in the maze was to increase the distance of D_1 and D_2 from the common food door (F_c). Figure 1 as drawn indicates this later arrangement). As in the former case, the rats were first taught the trick of pushing doors in a "straight-away." They then went through a period of alternate training on the three routes with the entrance at E_{11}. The training series was R_3, R_1, R_2, R_1, R_2, and repeated, and this was given on each day for twenty-nine days.

The detailed behavior during this training is presented in tables 6, 7, and 8. In these tables the numbers refer to the numbers of the routes entered; and those that are primed denote the doors at which the rats hesitated before entering. In table 9, the same facts are shown in a summarized form. Item B includes cases in which rats took R_2, but did not go so far as the door, D_2, as well as those in which rats reached D_2, whereas item C excludes cases of the former sort.

Tables 10 and 11 and Behavior Graph 1 show the results of the *test*. In table 11 the cases in which there were direct entries to R_2 from the entrance E_{II} are excluded, on the assumption that such entries would be likely to diminish the tendency of the rat to re-enter R_2 and therefore it would be unsafe to regard such failures to re-enter as indicative of the existence of the spatial insight that was being tested.

Fig. 2. Behavior Graph.

☐ = pushing without entering.
Δ = peeping.
O = turning before reaching the door.
X = hesitating.

Comparing tables 10 and 11 with table 9, one will find that there is an enormous difference, in terms of percentage, between the frequencies of entries to R_2 during the period of training and during the test.

Finally, it is inferred that this difference is unexplainable in any terms other than those of insight, and for the following reasons:

1. This preponderance of direct runnings from R_1 to R_3 cannot be accounted for by the distance to food, for R_3 is

evidently longer than R_2; nor by frequency, for there had been a much greater amount of training on R_2 than on R_3 nor by recency, for, according to the order of training in the alternate series, R_3 was less recent than R_2.

2. It seems difficult to regard such responses merely as natural responses, for the rats' original preference is evidently for R_2 rather than for R_3.

3. The direct runnings from R_1 to R_3 cannot be looked upon as habitual responses to the situation of D_1 being closed, for the results given in tables 1, 3, 4, 5, 6, 7, 8, and 9 clearly show this to be far from the case.

SUGGESTIONS

As this experiment is intended merely to determine the possibility of cultivating a specific kind of insight in the rat, the findings can serve only as preliminary to problems of insight-learning which may be formulated. Even in connection with this simple maze, the total problem, the writer believes, will not be adequately attacked until the relationship between the difficulty of cultivating insight and each of the following factors has been separately and carefully studied.

1. The order of alternation of training on the three routes.
2. The distance of D_1 and D_2 from the food door.
3. Variations in the direction of R_2.
4. Variations in the distance between R_1 and R_2.
5. Variations in the distance between R_2 and R_3.
6. Changing the entrance to a position to the left of R_1.
7. Increasing the number of doors or other obstructions in R_3.

LITERATURE CITED

Köhler, W.
    1927. *The Mentality of Apes*, p. 219.

Tolman, E. C.
    1927. "Habit Formation and Higher Mental Processes in Animals,"
        Psychol. Bull., 24:1–35.
    1928. "Habit Formation and Higher Mental Processes in Animals,"
        Psychol. Bull., 25:40–51.

HIGGINSON, G. D.
    1926. ''Visual Perception in the White Rat,'' *Jour. of Exper. Psychol.*,
        9:337–347.
GENGERELLI, J. A.
    1928. ''The Effect of Rotating the Maze on the Performance of the
        Hooded Rat,'' *Jour. Comp. Psychol.*, 8:377–384.

TABLE 1

THE BEHAVIOR OF ANIMALS IN THE COURSE OF TRAINING ON R_1
WITH ENTRANCE AT E_I

Rat	I	II	III	IV	V	VI	VII
A. Number of returns from R_2 into either R_1 or R_3	12	5	5	15	9	9	10
B. Number of returns from R_2 to R_3	8	2	3	9	5	5	6
B in percentage of *A*	67	40	60	60	56	56	60
C. Number of returns from R_1 into either R_2 or R_3	5	0	0	3	2	1	0
D. Number of returns from R_1 to R_2	3	0	0	3	2	1	0
D in percentage of *C*	60	....	....	100	100	100	....

TABLE 2

THE BEHAVIOR OF ANIMALS IN THE COURSE OF TRAINING ON R_3
WITH ENTRANCE AT E_I

Rat	I	II	III	IV	V	VI	VII
A. Number of returns from R_2 into either R_1 or R_3	13	20	11	10	11	8	7
B. Number of returns from R_2 to R_3	4	13	7	5	6	4	4
B in percentage of *A*	31	65	64	50	55	50	57
C. Number of returns from R_1 into either R_2 or R_3	12	13	15	11	19	16	15
D. Number of returns from R_1 to R_2	9	13	6	6	7	5	4
D in percentage of *C*	75	100	40	55	37	31	27

TABLE 3

THE BEHAVIOR OF ANIMALS IN THE COURSE OF TRAINING ON R_2
WITH ENTRANCE AT E_I

Rat	I	II	III	IV	V	VI	VII
A. Number of returns from R_1	2	2	5	2	1	6	10
B. Number of returns from R_1 to R_2	0	2	2	2	1	6	7
B in percentage of A	0	100	40	100	100	100	70

TABLE 4

THE BEHAVIOR OF ANIMALS IN THE COURSE OF TRAINING ON R_3
WITH ENTRANCE AT E_t

FIRST TWO DAYS

Rat	I	II	III	IV	V	VI	VII
A. Number of returns from R_1 to either R_2 or R_3	8	7	5	6	6	4	4
B. Number of returns from R_1 to R_2	8	7	5	6	5	3	4
B in percentage of A	100	100	100	100	83	75	100

THE FOLLOWING FIFTEEN DAYS

	I	II	III	IV	V	VI	VII
C. Number of returns from R_1 into either R_2 or R_3	4	6	10	5	13	12	11
D. Number of returns from R_1 to R_2	1	6	1	0	2	2	0
D in percentage of C	25	100	10	0	15	17	0

TABLE 5

THE BEHAVIOR OF ANIMALS IN THE COURSE OF ALTERNATE TRAINING
WITH ENTRANCE AT E_{II}

Rat	I	II	III	IV	V	VI	VII
A. Number of returns from R_1	18	18	22	18	29	22	19
B. Number of returns from R_1 to R_2	17	18	20	16	25	21	18
B in percentage of A	94	100	91	89	86	95	95

TABLE 6

THE BEHAVIOR OF RAT 1 IN THE COURSE OF ALTERNATE TRAINING

Day of training	Order of routes in the training									
	3	1	2	1	2	3	1	2	1	2
1st	12'112' 112'3	2'3' 111	2'12' 12	1	2	1212 12	1	2	1	112
3d	123	1	12	21	12	123	1	12	1	12
5th	1123	1'2'3 2'1	1'1'2	1	1'2	1'2' 3	1	1'2	1	1'2
7th	1'2'1'23	1	1'2	1	1'2	123	1	12	1	12
9th	123	1	12	1	12	123	1	12	1	12
11th	123	1	12	1	12	123	1	12	1	12
13th	123	1	12	1	12	123	1	12	1	12
15th	123	1	12	1	12	123	1	12	1	12
17th	123	1	12	1	12	123	1	12	1	12
19th	123	1	12	1	12	123	1	12	1	12
21st	123	1	12	1	12	123	1	12	1	12
23d	123	1	12	1	12	123	1	12	1	12
25th	123	1	12	1	12	123	1	12	1	12
27th	123	1	12	1	12	123	1	12	1	12
29th	123	1	12	1	12	123	1	12	1	12

TABLE 7

THE BEHAVIOR OF RAT 2 IN THE COURSE OF ALTERNATE TRAINING

Day of training	Order of routes in the training									
	3	1	2	1	2	3	1	2	1	2
1st....................	12'3	1	132'11 32	1	2	123	1	12	1	12
3d......................	23	1	12	1	12	123	1	12	1	12
5th....................	3	1'21	1'2	1	2	1'23	1	1'2	1	1'2
7th....................	1'23	1	1'2	1	1'2	123	1	12	1	12
9th....................	123	1	12	1	12	123	1	12	1	12
11th..................	123	1	12	1	12	123	1	12'312	1	12
13th..................	123	1	2	1	12	123	1	12	1	12
15th..................	123	1	2	1	12	123	1	12	1	12
17th..................	123	1	2	1	12	123	1	12	1	12
19th..................	123	1	2	1	12	123	1	12	1	12
21st..................	123	1	2	1	12	123	1	12	1	12
23d....................	123	1	12	1	12	123	1	12	1	12
25th..................	123	1	12'32	1	12	123	1	12'312	1	12
27th..................	123	1	12	1	12	123	1	12	1	12
29th..................	123	1	12'32	1	12	123	1	12	1	12

TABLE 8

THE BEHAVIOR OF RAT 3 IN THE COURSE OF ALTERNATE TRAINING

Day of training	Order of routes in the training									
	3	1	2	1	2	3	1	2	1	2
1st..........	12'3' 12'3'2' 1121'2' 3'2'3' 2'121' 2'3'2' 12'3	1	312	1	2	123	1	12	1	12
3d..........	123	231	12	1	12	123	1	12	1	12
5th..........	12'3	2'32 3'1	1'2	1	1'2	1'212' 23	1	1'2	23 2'1	1'2
7th..........	123	1	12	1	1'2	123	1	12	1	12
9th..........	123	1	12	1	12	123	1	12	1	12
11th..........	123	1	12	1	12	123	1	12	1	12
13th..........	123	1	12	1	12	123	1	12	1	12
15th..........	123	1	12	1	12	123	2323' 2321	12	1	12
17th..........	123	1	12	1	12	123	1	12	1	12
19th..........	123	1	12	1	12	12'3	1	12	1	12
21st..........	3	1	12	1	12	123	231	12	1	12
23d..........	123	1	12	1	12	123	1	12	1	12
25th..........	123	1	12	1	12	123	1	2	1	12
27th..........	12'3	1	12	1	12	123	1	12	1	1'2'12
29th..........	13	1	12'3 12	1	12	123	1	12	1	12

TABLE 9

BEHAVIOR DURING THE PERIOD OF TRAINING WITH REFERENCE TO R_2 AND D_2

Rat	A. Number of times R_2 was passed	B. Entries to R_2	B in percentage of A	C. Entries to D_2	C in percentage of A
1	101	100	99%	92	91%
2	103	97	94%	92	89%
3	118	102	86%	86	73%

TABLE 10

BEHAVIOR DURING THE TEST WITH REFERENCE TO R_2 AND D_2

Rat	A. Number of times R_2 was passed	B. Entries to R_2	B in percentage of A	C. Entries to D_2	C in percentage of A
1	14	5	36%	4	29%
2	10	3	30%	0	0%
3	12	4	33%	1	8%

TABLE 11

BEHAVIOR DURING THE TEST WITH REFERENCE TO R_2 AND D_2

Rat	A. Number of times R_2 was passed	B. Entries to R_2	B in percentage of A	C. Entries to D_2	C in percentage of A
1	12	4	33%	3	25%
2	10	3	30%	0	0%
3	11	3	27%	1	9%

HE GENETICS OF LEARNING ABILITY
IN RATS

PRELIMINARY REPORT

BY

ROBERT CHOATE TRYON

UNIVERSITY OF CALIFORNIA PUBLICATIONS

THE GENETICS OF LEARNING ABILITY IN RATS

PRELIMINARY REPORT

BY

ROBERT CHOATE TRYON

(Contribution under a fellowship from the National Research Council)

I. INTRODUCTION: THE PROBLEM

To what degree are individual differences in mental ability (i.e., ability to learn) due to hereditary factors, and to what degree due to environmental factors? The experiment here reported relates to this fundamental question in psychology. The method adopted for solving the problem was that of holding environmental factors constant and observing the inheritance of differences in mental ability. Such a method, for obvious reasons, was possible only with animals. In this investigation the mental ability dealt with was that of rats, and it was measured by their ability to learn a 17-unit T-maze.

Originally begun by Dr. E. C. Tolman in 1922, this inheritance problem gave preliminary results (Tolman, 1924) which, though encouraging, brought to light several subsidiary problems that had to be solved first. These preliminary problems involved: an improvement of the measuring scale which would increase the objectivity and reliability of measurement and make possible a determination of its validity; the introduction of better experimental control of environmental variables; the securing of a heterogeneous random sample of rats as the initial population; and the development of a better selection criterion which would insure rapid effects from selective breeding but at the same time prevent biological deterioration from inbreeding. How these preliminary problems have been attacked will be described in section II.

As initially formulated, the objective of the experiment was to establish by selective breeding Bright and Dull races of rats (Tolman, 1924, p. 2). A further objective has since been added, namely, the determination of the genetic mode of inheritance of this ability to learn. The second objective will be accomplished, it is believed, by applying the method used by geneticists in studying the inheritance of quantitative morphological characters, to-wit, by crossing the eventual "pure lines" and observing the behavior of strains derived from this cross.

II. EXPERIMENTAL PARTICULARS

A. THE MEASURING SCALE

1. *Objectivity of measurement.*—The measuring instrument is a 17-unit T-maze through which the animals run once a day for 19 days, and the score is the total number of entrances into blinds from days 2 to 19, inclusive. A revolving table on which the animals live during the entire experimental period is used in connection with the maze. The use of this table insures objectivity of handling the animals, for it automatically delivers each rat into the entrance of the maze and "collects" him at the end without the mediation of the experimenter. Objectivity of scoring is insured by the use of a device which automatically records his path through the maze. A complete description of this mechanical device together with a plan of the maze and experimental technique employed is fully set forth in a paper soon to appear (by Tolman, Tryon and Jeffress).

2. *Reliability for differentiating individuals.* On the original parental sample of 142 animals, a reliability coefficient above .95 was found for total errors made in the 18 days of running. Even for errors on runs for only 3 days at some stages of learning, the coefficient reached a magnitude of .90. This reliability of measurement compares favorably with the best mental tests for human beings. A full discussion of the reliability of this maze is given elsewhere (Tryon, 1928).

3. *Validity as a measure of ability to learn.* To see if the automatic maze measured in general the same sort of learning ability as would be employed in the learning of other mazes, that is, to see if it measured some deep-seated adaptive capacity in the animals, a second maze, differing in design and operated under quite dissimilar experimental conditions from those of the automatic maze, was utilized. The original parental sample was

run on this second maze after experiencing the first. The correlation (corrected for attenuation) between three-day stages of learning on one maze and three-day stages on the other was, in some cases, above .90. The raw correlation between total performance on the automatic and on the second maze was in excess of .80. These correlations indicate that the automatic maze differentiated the animals in some general fundamental ability which is likewise employed in learning another maze. A diagram of both mazes and a discussion of the community of function measured by them is given elsewhere (Tryon, 1928).

B. Experimental Control of Environmental Factors

The animals are housed in a specially constructed living room, automatically heated so as to prevent extreme temperature variation. They are bred in special breeding cages, their offspring numbered at weaning time, the siblings separated and distributed into cages which contain, within practical limits, equal numbers of progeny of Bright and Dull parents. The purpose of this separation is to wipe out special environmental factors which might affect siblings similarly if they were kept together. When the time comes to run the maze, each animal is placed alone in a special compartment in the revolving table, and is not touched, except for weighing on days 1, 8, and 19, and during a special preliminary run of 8 days. This preliminary run is designed to acquaint the animals with the special features of the maze which might frighten them if they were suddenly introduced into the maze proper, and this practice is constant for all animals. On the ninth day and thereafter, each animal runs through the maze to his home compartment, where he gets his only food and water for the day. Regarding the control of sensory stimuli: the paths of the maze are illuminated by an indirect lighting system; every effort has been made to insure

that no special sensory acuity may be utilized in running the maze; and the maze room is isolated from extraneous noises which might disturb the animals.[1]

C. The Original Parental Sample

A primary requisite of this experiment was to secure an exceedingly heterogeneous sample of rats as the initial parental group. The object was to have present in this biological sample the whole range of rats' mental ability. To satisfy this demand, the individuals of the parental group were chosen from many litters, the parents of which were unrelated for many generations. That wide differences were actually obtained is indicated by the high magnitude of the reliability coefficient of this sample.

D. The Selection Criteria for Breeders

Success in establishing pure lines of Bright and Dull rats depends upon the degree of excellence of criteria by which, in any given generation, breeders are picked out that shall produce progeny deviating to the greatest degree in the direction of their given parents. After selection through three generations, the following criteria have been developed, and these are used in selecting breeders.

1. *Score on the learning scale.*—The first consideration is the actual error score which the individual rat earns in running the maze. At first it was thought that a weighted score would be

[1] Whether the food incentive was sufficiently controlled has not as yet been fully determined. Animals of the same sex were fed the same quantity of food. If this procedure penalized the heavy animals and over-fed the lighter ones, then one would anticipate the existence of a correlation between initial weight or change in weight and maze performance. Though these correlations have not as yet been computed, superficial scanning of the records leads the writer to believe that such correlations, if not zero, are negligible.

Certain other variables which were not controlled are: age at learning (which varied between 75 days and one year), sex, and coat color. These variables have been measured, however, but correlations between them and maze-performance have not as yet been computed. General observation leads the writer to anticipate that these correlations, when computed, will be of small magnitude.

the best. This refined score was to be composed of the scores on successive stages of learning, each stage weighted roughly in proportion to its reliability and validity coefficients (Tryon, 1928). It was found, however, that the successive stages of learning were "naturally" weighted according to these coefficients, and that the raw total score was good as it stood, for the natural weights (sigmas) of the successive stages were roughly proportional to their respective coefficients. That the sum of the errors on 18 days is a good measure as it stands is further indicated by its high reliability and its correlation with the score on the second maze.

2. *"Kin-performance."*—Simple assortative mating was used at first in choosing mates to be the parents of the F_1 animals. Bright was bred with Bright, and Dull with Dull. While some difference between F_1 children of Bright and Dull appeared, it was not great, as will be shown later. The writings of Sewall Wright, Gowen, and others interested in the genetics of quantitative morphological characters then suggested to the writer the use of some modification of the breeders' method called the "progeny test." This test consists in gauging the genetic composition of an individual by the performance of his progeny. But in this experiment, for many reasons, one generation is killed off before its progeny have been tested. A criterion of "kin-performance" was therefore devised, to-wit, the gauging of an individual's genetic constitution (in addition to using the information which his *own* performance gives) by that of his kin, i.e., his siblings, step-siblings, parents, uncles and aunts, grandparents, and more remote relatives. This criterion was used in selecting the parents of the F_2. But its use is difficult; for if one has, say, 50 individuals to choose from as potential breeders, the total number of kinsmen is great. To facilitate the use of this criterion, the experimenter has recently devised and begun to use a graphical method which enables him to observe on one chart the performance of an animal's litter-mates, step-sibs, cousins, and parents, and on other charts, the performance of

more remote ancestors. There is only one chart for each generation. Incidentally, this chart at the same time shows the degree of inbreeding, and the fertility of the family from which each individual comes.

3. *Degree of inbreeding.*—Inbreeding must be resorted to in order to hasten the production of animals homozygous for factors that produce brightness and dullness, but such inbreeding must not be so close as to permit piling up of homozygous cacogenic factors which produce characters that may be deleterious to the strain. The following method has been adopted: brother by sister matings comprise the parents roughly of half of a given generation; the other half of the parents are more remotely related. In the next generation, of those who are selected for breeders, the individuals whose fathers and mothers were siblings are mated with rats *not* their siblings, whereas, the individuals whose parents were not siblings are mated, if possible, *with* siblings. This method will produce a much more rapid degree of homozygosity for mental ability than for other characters which may be cacogenic, and hence will enable the experimenter to eliminate the deleterious factors before they may affect any large number of rats.

4. *Fertility.*—Another requisite is the development of strains which are highly fertile. This is essential in order not only to be sure that a strain will perpetuate itself, but also in order to secure enough children of a given set of parents to enable the experimenter to gauge the genotypic make-up of the parents and of their offspring. Say that a given pair of parents by test are Bright, and all of their children by test are Bright also, then it is plausible to suppose that this family is to a fair degree homozygous for many of the factors underlying Brightness. On the other hand, say that a given pair of parents by test are Bright, but that their children vary over the whole scale of performance. Then it is plausible to suppose either that, while the parents had many factors for brightness, they were very heterozygous in this regard, hence the "spread" of their children, or that

environmental factors had operated to occasion a bright performance of genetically mediocre parents. As between these two families, parents of succeeding generations should obviously come from the first. But to make use of such data it is necessary to have large families. This demand is being satisfied in the following way: At the time when the parents are being selected for the next generation, a rather large number are chosen to breed. All of those which produce offspring are *once again* bred to their former mates. Only those children are kept whose parents have thus littered on both occasions. This criterion attains three objects: (*a*) it retains a line which is highly fertile *per se*, and (*b*) it secures a fairly large number of children of a given set of parents. Of psychological importance, (*c*) it secures two types of offspring, *twins* (members of the same litter) and *siblings* (members of different litters by the same parents).

5. *Physique.*—Only those rats are selected as parents that have a family and personal history of sound physical health.

6. *Color.*—An effort is made to keep the stocks as heterogeneous in color as possible. The value of this is not so apparent at the present stage of the experiment, but after pure lines have been established, then an attempt will be made by proper breeding to *fix* (make homozygous) a certain coat pattern and color to the Bright strain, and another pattern and color to the Dull. These lines may then be kept in stock without fear of contamination by other strains.

III. ANALYSIS OF RESULTS

A. RESULTS WHICH RELATE PARTICULARLY TO THE *Degree* TO WHICH THIS ABILITY TO LEARN IS INHERITED

This mental ability must appear to be inherited if, as one passes from generation to generation, one finds that there is an increasing tendency for Bright to beget Bright, and Dull to beget Dull. In successive generations one would expect the offspring of Bright and Dull parents to become more and more different from one another until in an *n*th generation this difference reaches a maximum. The Bright and Dull lines will then be as pure as possible under our conditions of measurement. Evidence which will reveal the degree to which this mental ability is inherited will appear from two types of analysis: (1) from a comparison of frequency histograms in successive generations, and (2) from the change in group statistical constants in successive generations (i.e., by comparing means, standard devia-· tions, correlation coefficients, etc.).

NOTE ON THE MEDIAN GROUP

At the outset of the experiment, it was decided as a precaution to use also a Median group for the first few generations. In the event that either the Bright or Dull group failed to perpetuate itself, then suitable individuals from the Median group were to be chosen to brace up, as it were, the failing group. Indeed, this precaution proved wise, for a number of the Dull parents of the F_1 and F_2 were sterile. From the Median F_1 group (i.e., those F_1 whose parents were Median) many whose performance was Dull were used as parents of the Dull F_2. But both Bright and Dull parents of the F_3 proved very fertile so that this Median group has now been dispensed with. Future generations will be composed only of Bright and Dull lines.

1. *Evidence from the comparison of the distributions of the groups.*—In figures 1, 2, and 3 are given the histograms of the groups in the P, F_1, and F_2 generations respectively. The *scale* (of abscissae) drawn at the top of the figures requires some

explanation. The distribution of the parental sample of animals was originally drawn on a scale of equal width intervals and was found to be very skewed. This skewness was due to the fact that the dull end of the scale spread out inordinately. For practical purposes, the distribution was warped into a symmetrical shape by transmuting the original scale into the new scale shown above the figures. In this scale, the values 0, 1, 2, 3, ... 18, mean increasing degrees of dullness. To illustrate, class 0 contains those individuals making from 10 to 14 errors, class 9, from 55 to 64 errors, class 18, from 195 to 214 errors. A justification of this procedure will be given elsewhere.[2]

The parental generation (P). The distribution of the errors made by the initial random sample of 142 rats is shown in figure 1. This was the original group from whose records the data on reliability and validity of the maze were secured. The variation in this group is very large, ranging from 11 errors to 195 errors. From this group, Bright, Median, and Dull breeders were selected as parents of the F_1 as denoted by the cross-hatching in the figure (see legend at bottom of figures).

The F_1 generation. The P Dull parents gave too few progeny. The F_1 children of Dull and Median P parents were therefore thrown into one distribution and compared with the progeny of Bright parents (see fig. 2). The difference between the means (M's) of the progeny of Bright and Median-plus-Dull is not great in this generation. It may be noticed, however, that there is a marked tendency for the Median-plus-Dull group to collect in the rather dull classes from 13 to 18, whereas fewer of the Bright group are found in these categories. The progeny of Bright tend to collect in categories 1 to 3 more than do the Median-plus-Dull. But the variation in both groups is so great as to produce a high degree of overlapping.

---

[2] A more important consideration than transmutation, however, is to know the *reliability* of each point on the scale, that is, to know the degree to which individuals fluctuate *by chance* from one class to another. The probable error of each point is important, because, in the selection of breeders, one should know the degree to which each individual is reliably different from each other individual. The reliability of these scale points has not as yet been determined.

P
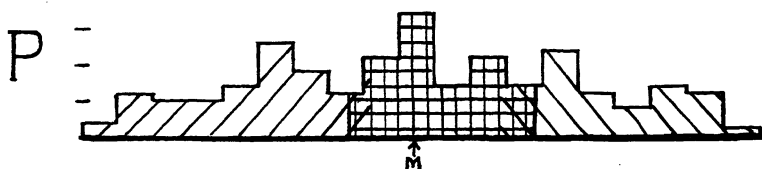
Fig. 1. Distribution of scores of Parental Group (N = 142).

(a) Progeny of Bright P (N = 66).

F_1

(b) Progeny of Median-plus-Dull P (N = 130).

Fig. 2. Distribution of scores of F_1.

(a) Progeny of Bright F_1 (N = 94).

(b) Progeny of Dull F_1 (N = 72).
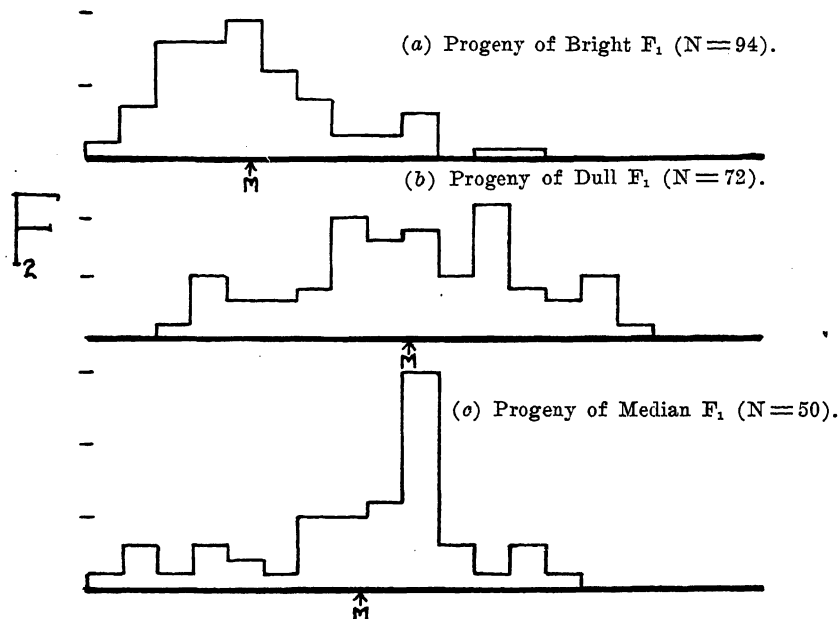
F_2

(c) Progeny of Median F_1 (N = 50).
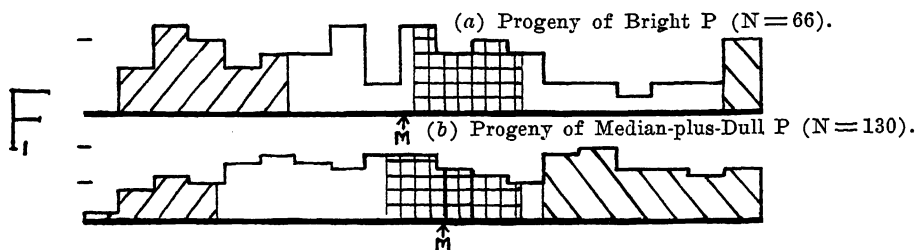
Fig. 3. Distribution of scores of F_2.

In figures above, the ordinate of each distribution refers to number of individuals, the abscissa to scale at the top. M is the mean point. Barring denotes region from which mates are selected, to-wit:

Bright mates.   Median mates.   Dull mates.

Such a slight difference between (*a*) and (*b*) in figure 2 is probably due to the fact that the Median-plus-Dull group contained progeny from 16 Median matings and only 6 Dull matings, so that the comparison is largely that between Bright and Median.   The Dull P parents produced only 6 litters from 29 matings.   It is supposed that a greater difference would have been obtained had a larger group of Dull P parents been fertile.

The F_2 generation.   There were more individuals in the F_1 than in the P generation from which to select suitable mates as parents of the F_2, and kin-performance was added to own-performance as a criterion in the selection of the parents of the F_2.   These mates proved more fertile than their predecessors.   A certain proportion of matings were brother by sister.   The effect of the improved criteria of selection for parents is quite noticeable in the F_2.   (See fig. 3, distributions *a*, *b*, and *c*.)   Special attention should be drawn to distributions (*a*) and (*b*), children of Bright F_1 and Dull F_1.   These two distributions are now distinct, and overlapping has been greatly diminished.

The F_3 generation.   The Median group has been discontinued and all effort concentrated on the rapid production of Bright and Dull races.   The F_2 Bright and Dull parents of the F_3 have proved to be quite fertile.   The improved criteria have been put in full operation in the selection of the parents of the F_3, but scores from this generation are not as yet available.

2. *Evidence from the comparison of statistical constants on successive generations.*—(*a*) Evidence from the change in means: As the effects of selection become more and more pronounced in successive generations, one would expect the differences between mean scores of the Bright and Dull strains to become greater until pure lines, or at least highly homozygous lines, have been established, when the difference will reach a maximum.   Table 1 presents the mean scores and their differences to date.

TABLE 1

COMPARISON OF MEAN SCORES

	Mean of progeny of Bright	Mean of progeny of Dull	Difference between means
F_1	8.58±.42	9.66±.30 (Median-plus-Dull)	1.08±.51
F_2	4.18±.16	8.69±.25	4.51±.30

This table shows that the difference between Bright and Dull strains has increased in the F_2 over that of the F_1. The increased difference, 4.51, is fifteen times its P.E.,[3] and is therefore statistically very reliable.

(*b*) Evidence from the change in variability: Selection, if effective, should produce more homogeneous strains at successive generations, that is, the standard deviations should decrease until, at the time the races are pure, they should reach a minimum. Table 2 gives these sigmas to date.

TABLE 2

STANDARD DEVIATIONS OF THE SCORES OF THE VARIOUS GROUPS

	Bright	Median	Dull
P		4.50±.18	
F_1	5.01±.30	4.98±.21	
F_2	2.43±.11	3.07±.30	3.18±.25

Note that in table 2, no decrease in sigmas appeared in going from the P to F_1. The F_1 strains were therefore no more homogeneous than the P group. But in going from the F_1 to F_2, the strains underwent marked diminution in heterogeneity. In the Bright strain the variability was cut in half, from 5.01 to 2.43, in the Dull to about three-fifths, from 4.98 (including the Median group) to 3.18.

[3] The numbers after ± are the orthodox errors, to wit,

$$\text{P.E.}_{M_1} = .6745 \frac{\sigma_1}{\sqrt{N_1}}, \quad \text{P.E.}_{M_1 - M_2} = .6745 \sqrt{\sigma^2_{M_1} + \sigma^2_{M_2}}, \quad \text{P.E.}_{\sigma_1} = .6745 \frac{\sigma_1}{\sqrt{2N_1}}$$

(c) Evidence from the correlation between kin: Since the correlation coefficient between two variables such as those in which we are interested is a measure of how much both are determined by a common cause, in our case the germ plasm, the correlations between different classes of kinsmen are important. The correlations will be between twins, siblings, parent-offspring, cousins, uncle-nephew, grandparent-grandchild, etc. Such correlations have been secured for some human traits, but environmental factors have not been excluded. In this investigation, where environmental factors which would make for a correlation between kinsmen have been eliminated, the correlation coefficients must be secured for each generation separately, the maximum values being reached, theoretically at least, when the pure lines have been developed.

TABLE 3

COMPARISON OF THE FERTILITY OF THE STRAINS

	Parents	Number of matings	Number fertile	Per cent fertile	Number of progeny	Average number per litter
P	Bright..........................	29	11	38	80	7.3
	Median........................	40	16	40	110	6.9
	Dull.............................	29	6	21	38	6.3
F_1	Bright..........................	36	34	94	254	7.5
	Median........................	33	14	42	89	6.4
	Dull.............................	51	22	43	130	5.9
F_2	The per cent of Dull F_2 matings that have proved fertile have so far equaled that of Bright, though the statistics on this group have not been completed					

NOTE ON THE DIFFERENTIAL PARTIAL STERILITY IN THE
P AND F_1

Surprising results in the fertility of Bright and Dull strains appeared early. The Bright animals have been superior to the Dull in two ways: in the number of matings which have proved fertile, and in the number of children per mating. Table 3 shows these results to date.

The Bright were most fertile and had the largest number of progeny per litter in the P and F_1. Both the Bright and Dull were twice as fertile

in the F_1 as in P, but the Dull remained less fertile than the Bright. In the F_2 the Dull group appeared to be as fertile as the Bright. This increasing tendency for the stocks to become more fertile as the experiment progresses is due, I believe, to the procedure of keeping children whose parents were fertile *twice*, and excluding others.

It may *not* be argued from the data on fertility that the mental ability, especially as measured in the F_2, is *closely* related to physical vigor of which fertility seems to be an index, for the F_2 Bright and F_2 Dull groups, which have shown wide differences in mental ability, appear to be equally fertile.

NOTE ON THE GENERAL IMPROVEMENT IN THE F_2 OVER PRECEDING GENERATIONS

Notwithstanding the fact that the Bright line appears to have become more different from the Dull line at successive generations, the amazing fact exists that *both* groups have done *better* in the F_2 than in the F_1 or P. Notice that in the Dull group of the F_2 (fig. 3) there are few cases in the categories 15 to 18, whereas in figures 1 and 2 there are many. A subsequent generation has therefore improved over a preceding one—a nice bit of evidence for one who accepts the hypothesis that there is inheritance of acquired characters. But other explanations may be offered:

1. As this investigation has progressed, the experimenter and assistant who cares for the animals have necessarily become more skilled in handling them. But if there have been any changes in *technique*, they have been unconsciously made, for the technique was laid down at the beginning of the experiment, and it has not been deviated from in any essential respect.

2. Possibly there has been a progressive decrease in timidity due to social influence of one generation, docile by training, upon the next. Such progressive decrease in timidity might also be explained by the increased skill in the handling of the animals. Such an hypothesis is not convincing to the experimenter, for up to the time the rats began running the maze, they appeared to be just as timid in the F_2 as in the P.

3. The theory most plausible to the experimenter is that general improvement of the F_2 over the F_1 and P is due to the increased vigor of the F_2 in both the Bright and the Dull strains. Individuals from these latter groups showed a heightened vigor in the maze, explored more actively, and never refused to run. This increase in vigor is due, I believe, to the selection occasioned by the partial sterility of the P and F_1 In general, strains more fertile and more vigorous physically are being developed and hence they are more active in learning. The less fertile and less vigorous strains have not perpetuated themselves.

B. Results which Relate to the *Mode* of the Inheritance of this Mental Ability

Other investigations in genetics on the establishment of pure lines have in the main considered the measurement of structures in plants and animals. These characters are similar to mental ability in that they vary continuously. The inheritance of these characters has been explained by the operation of multiple genetic factors; and by proper breeding experiments, results in many cases appear which are consonant with the multiple-factor hypothesis and are explicable by no other theory. This hypothesis applied in its pure form to mental ability would assume that one extremity of this trait, say Dullness, is caused by n factors, such as $aabbcc \ldots nn$, where each factor is independent and of equal weight; the other homozygous extreme, Brightness, is caused by N allelomorphic factors, $AABBCC \ldots NN$, where each factor is independent and of equal weight. Regarding such allelomorphs as $A-a$, the large letter represents one factor for Brightness, the small, one for Dullness. No dominance is postulated, the heterozygous state produces an intermediate condition, and the factors interact cumulatively, i.e., the more large letters present, the brighter the individual. If the number of factors determining mental ability is large, however, these assumptions are not mandatory, that is, dominance may operate between some allelomorphs, factors may be of different weights, they may not assort independently (i.e., they may be linked) and yet the character, mental ability, may appear to be inherited according to the ideal multiple-factor scheme.

The question is: Are the results obtained to date consonant with the multiple-factor theory?

Since the parental group was a sample chosen at random from the rat population, it was probably very heterogeneous genotypically. The group was too small for one to expect pure

remes to be present, especially if the number of factors operat-
is large. Theoretically, the sample, since it was very hetero-
ous generally, would group about the most heterozygous type,
$BbCc \ldots Nn$. A few of the more extreme types would exist,
course, containing on the one hand, a preponderance of large-
tered factors, on the other hand, a preponderance of small-
tered factors. Singling out these extreme types, inbreeding
m to secure eventually pure lines, $AABBCC \ldots NN$ and
$bcc \ldots nn$, is the first objective of the experiment. But
the F_1 only moderate success can be anticipated. Parents
Bright F_1 would still be very heterozygous, containing many
all-lettered factors, and consequently, by the principle of inde-
dent assortment, a variable F_1 group would be produced.
nilarly, the Dull parents would likewise be very heterozygous,
ducing also a variable F_1. The results as shown in figure 2
in accordance with these theoretical expectations. In view
the fact that the Bright parents were in some cases (see fig. 1)
ost average in ability, and that the Dull parents were very
ertile, so that the parenthood of the Median-plus-Dull F_1 was
gely that of Median heterozygous parents, one would expect
t the children of Bright and Median-plus-Dull parents would
er little in the means and would overlap enormously.

Since the total F_1 was a larger group than the P, more suc-
s was had in securing extreme types for breeders. The Bright
ents were all more definitely Bright, though doubtless much
erozygosity existed among them. Similarly, a quite Dull set
parents was secured, sufficiently fertile to produce for the first
e a group large enough for comparative purposes. In some
es, brother-by-sister matings were made. As a result, the
ldren of Bright and Dull F_1 parents formed quite separate
tributions (fig. 3). While there is still much variability within
h group, overlapping among groups has greatly diminished.

Consonant with the multiple-factor theory, the distributions
behaving in such a fashion as to indicate that we are
inning to shuffle the factors into two piles, those consisting of

determiners for Brightness and those for Dullness. The rapidity with which this may be done hinges upon (1) our ability to run large numbers which will increase the probability of extreme types occurring (it is for this reason that the Median group has been dispensed with, in order to concentrate upon the Bright and Dull groups), (2) the degree to which brother-by-sister matings may be resorted to without piling up on cacogenic factors, and (3) the number of factors producing this mental ability (the greater the number, the longer the time of sorting).

Final decision as to the mode of inheritance must await the crucial crosses which will be made when relatively pure lines are established. If multiple-factors operate, then crosses between the eventual pure lines of Bright, $AABBCC \ldots NN$, and Dull, $aabbcc \ldots nn$, will produce an F_1 all of the median homozygous type, $AaBbCc \ldots Nn$, and the F_2 will vary over the whole range of performance. Such results, or close approximations to them, will demonstrate that this mental ability, to the degree that it is inherited, is explainable by the Mendelian multiple-factor formula.

IV. SUMMARY AND PROSPECTUS

The *object* of this investigation has been defined as the determination of the degree to which this mental ability (maze-learning of rats) is inherited, and of the nature of the genetic factors which produce it.

The *procedure* is as follows: Beginning with an original heterogeneous sample of progenitors, selective breeding has been resorted to with the expectation of obtaining two pure lines of Bright and of Dull individuals. These races, if obtained, will be interbred, and the results of these crosses will indicate the nature of the genetic factors underlying the trait.

The *experimental technique* contains these features: an objective, reliable, and valid measuring scale; some environmental variables controlled, and those not controlled, directly or

indirectly measured; an original sample of rats carefully selected so as to include a random sample of ability; selection criteria developed which aim at the rapid production of pure lines in mental ability but which at the same time eliminate cacogenic characters.

The *results* on the P, F_1, and F_2 generations indicate that this mental ability is inherited, in part at least, and there is reason to believe that pure lines may be obtained. The results so far are consistent with what would be anticipated if this trait were produced by multiple genetic factors.

LITERATURE CITED

TOLMAN, E. C.
  1924.   "The inheritance of maze learning in rats." *Journal of Comparative Psychology*, 4:1-18.

TRYON, R. C.
  1928.   "Individual differences at successive stages of learning." Manuscript Ph.D. thesis, deposited in University of California Library.
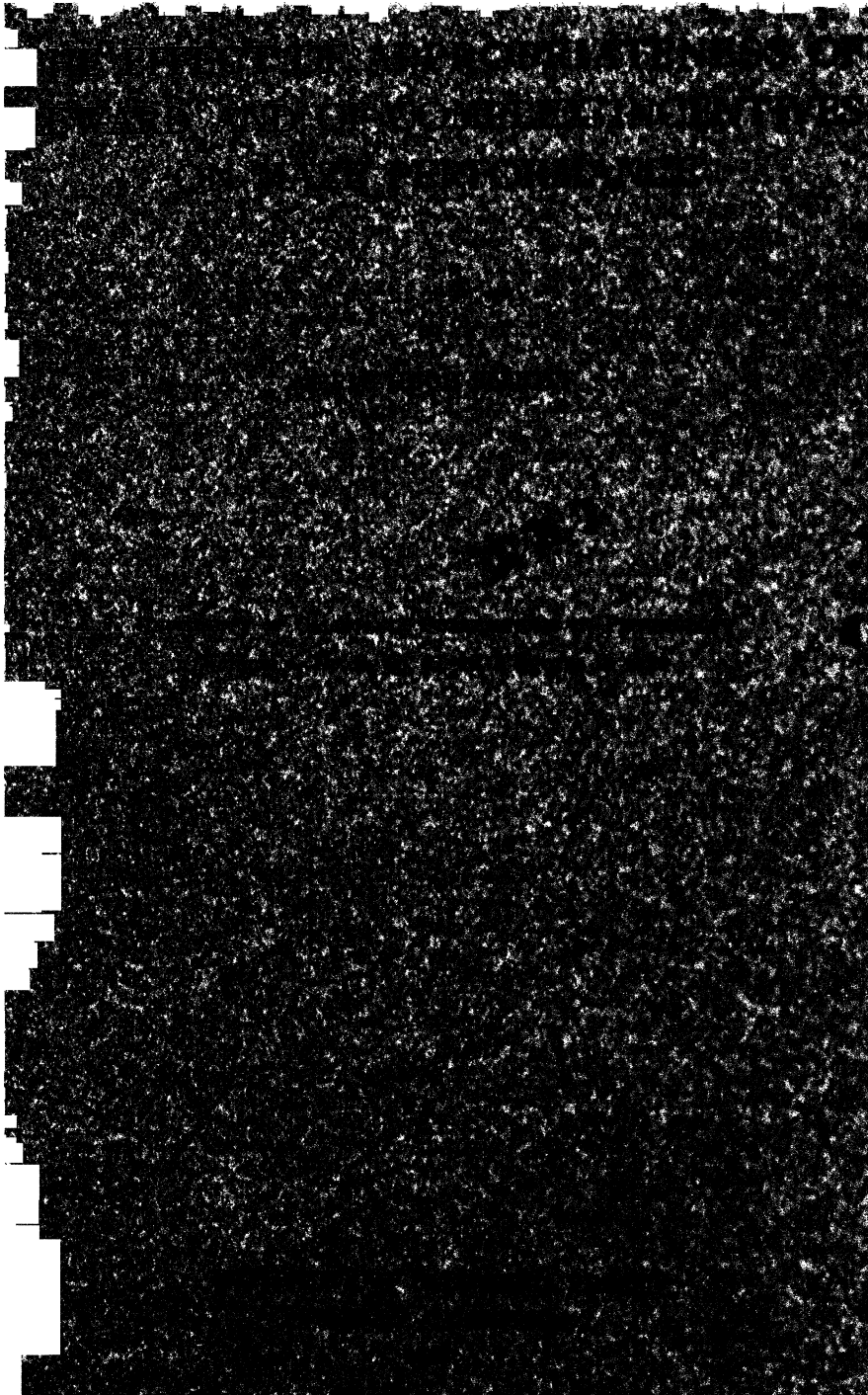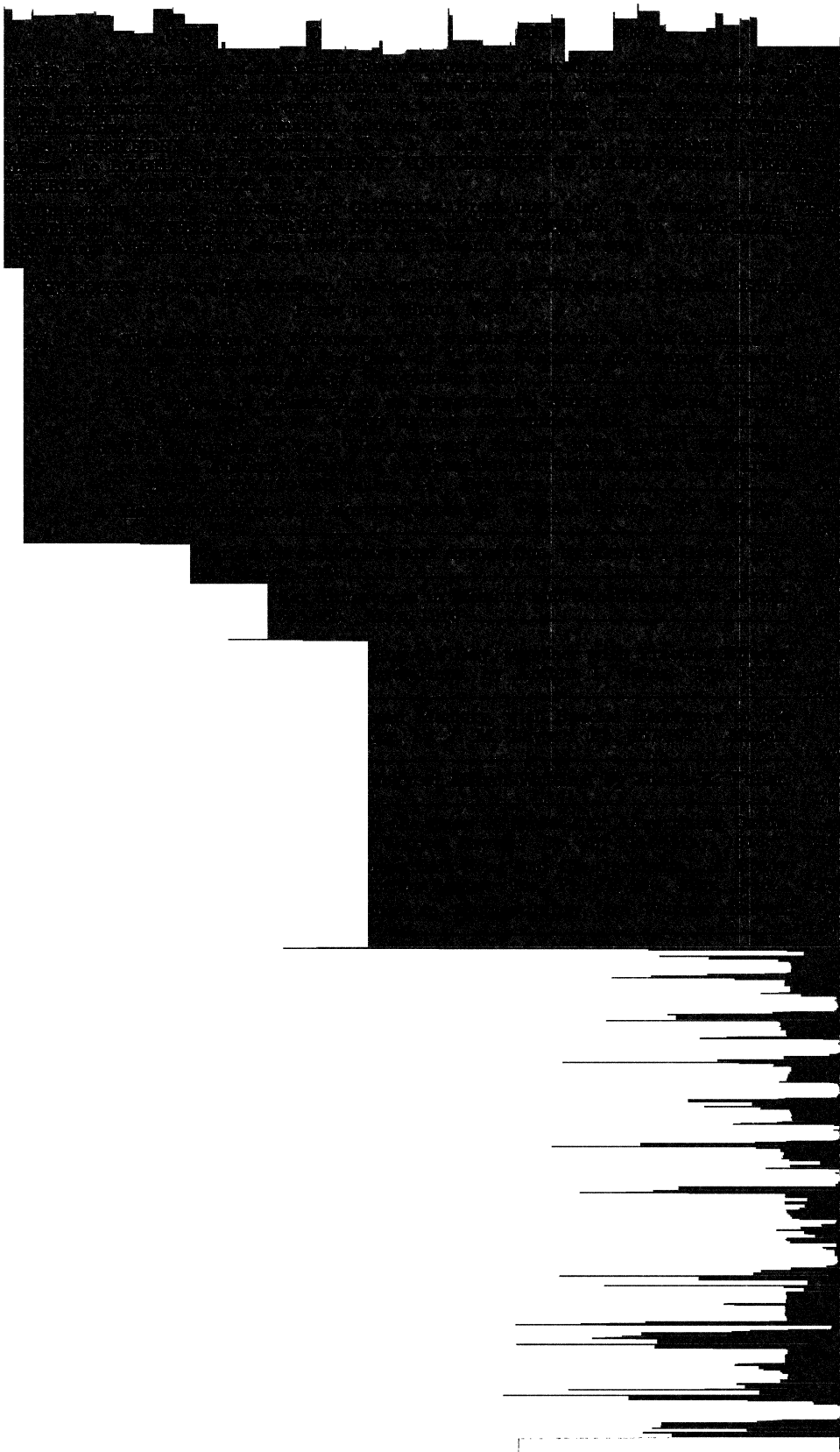
THE EFFECT OF
APPROPRIATENESS OF REWARD AND OF
COMPLEX INCENTIVES ON MAZE
PERFORMANCE

BY

MERLE HUGH ELLIOTT

PROBLEM

The first object of this study was to determine the effect of the appropriateness of the reward[1] upon the maze performance of rats. A second object was to determine the effect of the presence of two drives upon such maze performance.

METHOD

The same maze and the same general technique were used as in the study previously reported (Elliott, 1928). The rats were given one trial per day on a 14-unit multiple-T maze and were scored in terms of time and errors.

PROCEDURE

Three experimental groups were used. All three groups were both hungry and thirsty throughout the training period. All

---

[1] "Reward" is defined as the object placed in the endbox of the maze. "Drive" is defined as the internal state of the animal resulting from deprivation of food or water, i.e., hunger or thirst. "Appropriateness" is defined in terms of the relationship of reward to drive.

three were rewarded with bran mash[2] for the first nine days, which was changed to the water reward for the remaining nine days of training. The three groups differed from one another only in regard to the relative strengths of the two drives which were simultaneously present.

All the animals were fed the remainder of the day's ration in the living-cages one hour after the daily maze trial. The regimen of the various groups was otherwise as follows:

Group E—

This group consisted of 28 male rats which were both *very hungry* and *very thirsty*. The water bottles were taken out of the living-cages eight hours before the maze trials and the animals were at the same time given a small amount of dry bran mash.

Group F—

This group consisted of 25 male rats which were *very hungry* and *slightly thirsty*. The water bottles were removed half an hour before the maze trials, and no dry food was given.

Group G—

This group consisted of 22 male rats which were *slightly hungry* and *very thirsty*. The water bottles were removed eight hours before the maze trials and large containers of dry food placed in the living-cages. The thirst was intensified by the dry food, and the animals ate only until some degree of balance was reached between the increasing thirst and decreasing hunger. (If they were now given water, they would then eat more of the dry food. Likewise, they were still able to eat the slightly moistened food which was used as a reward for the first nine days. See footnote 3.)

[2] This was a modification of the Steenbock diet. Two parts by volume of the food were combined with one part of water to produce a dryish mixture which it was thought would not quench the thirst of the animals and at the same time would not aggravate it.

RESULTS ON APPROPRIATENESS OF REWARD

Figures 1 and 2 give the average performance of each of the three groups in terms of errors and time, respectively. In order to show the significance of the various changes in performance
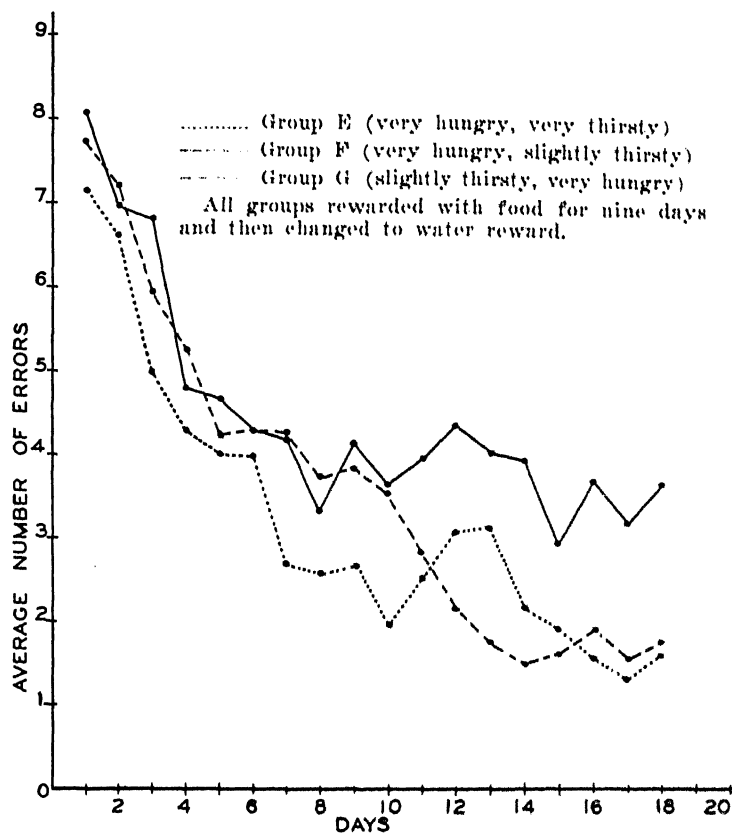
Fig. 1

resulting from the change of reward, the following tables are presented. In each of these tables are given the differences between the mean for the tenth day and that for each of the succeeding days, divided by the standard deviation of those differences (i.e., $\dfrac{\text{Diff.}}{\sigma \text{ diff.}}$). In these tables the $+$ sign preceding

the ratio indicates that the mean performance on the particular day is above (i.e., poorer than) the performance of the group on day 10, while the — sign indicates that it is below (i.e., better).

TABLE 1

RELIABILITIES OF THE DIFFERENCES OF THE MEANS OF GROUP E

Days compared	10–11	10–12	10–13	10–14	10–15	10–16	10–17	10–18
$\dfrac{\text{Diff.}}{\sigma \text{ diff.}}$ (errors)	+1.06	+2.36	+2.38	+ .44	− .14	− .98	−1.60	− .90
$\dfrac{\text{Diff.}}{\sigma \text{ diff.}}$ (time)	+2.00	+4.26	+3.44	+2.68	+2.15	+1.52	+1.27	+1.47

TABLE 2

RELIABILITIES OF THE DIFFERENCES OF THE MEANS FOR GROUP F

Days compared	10–11	10–12	10–13	10–14	10–15	10–16	10–17	10–18
$\dfrac{\text{Diff.}}{\sigma \text{ diff.}}$ (errors)	+ .45	+ .82	+ .50	+ .36	−1.10	− .00	− .77	− .06
$\dfrac{\text{Diff.}}{\sigma \text{ diff.}}$ (time)	+ .87	+1.20	+3.60	+2.94	+2.65	+3.16	+2.22	+2.93

TABLE 3

RELIABILITIES OF THE DIFFERENCES OF THE MEANS FOR GROUP G

Days compared	10–11	10–12	10–13	10–14	10–15	10–16	10–17	10–18
$\dfrac{\text{Diff.}}{\sigma \text{ diff.}}$ (errors)	−1.24	−1.77	−2.46	−3.03	−2.77	−2.21	−2.81	−2.57
$\dfrac{\text{Diff.}}{\sigma \text{ diff.}}$ (time)	−1.11	−1.54	−2.29	−2.61	−2.51	−2.45	−2.67	−2.35

The rats of Group E, which were both hungry and very thirsty, showed, when the reward was changed from food to water, an increase in both time and errors and then returned

approximately to their former level of efficiency. The ratios in table 1 indicate that the time scores tended to lag behind the error scores in this return.
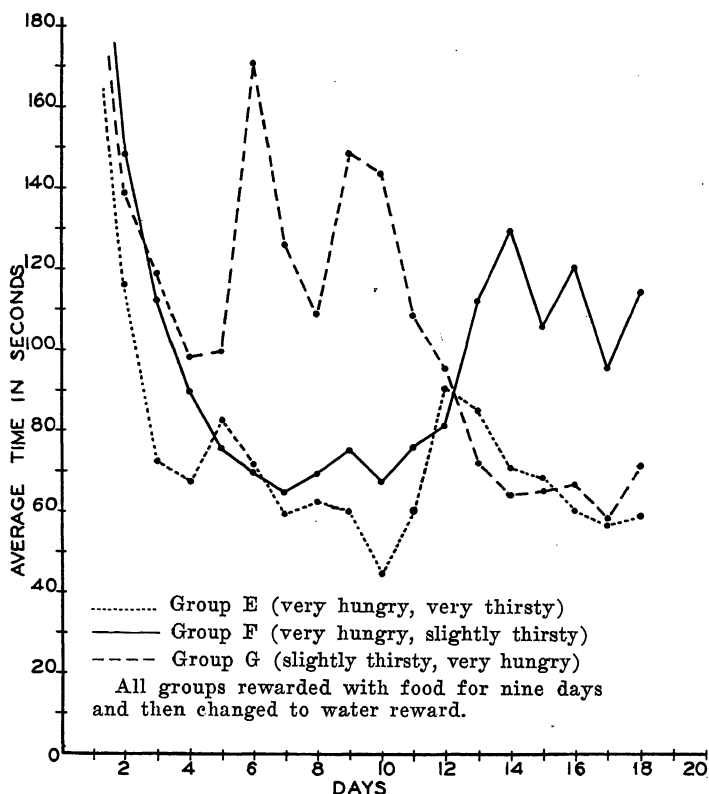
Fig. 2

In the case of Group F, whose members were very hungry and only slightly thirsty, we find a decided increase in time as a result of the change of reward from food to water. The errors, however, continued at about the same level as shown in table 2. These animals were decidedly upset by the changed condition of reward. Their usual behavior on arriving at the reward box (after the change) was to drink a little water and then to struggle wildly to escape. If anthropomorphism be permitted,

one would describe these animals as extremely excited, emotionally disturbed, and occasionally neurotic.

In table 3 we see that the rats of Group G, which were slightly hungry and very thirsty, showed a distinct decrease in both time and error scores when the reward was changed from the food to water. Four of the rats in this group showed "disappointment" on the tenth and eleventh days. That is, after first drinking a little water, they either struggled to escape or spent the time in scratching or searching. Aside from this, there was no indication of dissatisfaction with the water reward.

RESULTS ON THE EFFECT OF A COMPLEX INCENTIVE

The animals of groups E and F were very hungry, and were running for the food reward during the first ten days.[3] Group E had also a strong thirst drive. Both the error and time scores during the first ten days suggest that the presence of two strong drives, only one of which is rewarded, is more effective in facilitating learning than is the one rewarded drive alone.

DISCUSSION AND CONCLUSIONS

The fact is well established that different rewards vary in their effectiveness. Simmons (1924), for example, has shown that "bread-and-milk and sunflower-seed both appeal to the hunger motive, ... and yet we get a difference in records with the two rewards." The same thing is shown by the two groups previously reported (Elliott, 1928), which were rewarded for ten days with bran mash and sunflower seed, respectively. Hence we may postulate a factor, "reward-value,"[4] which will vary in strength for different rewards, given one and the same drive. This "natural" reward-value may, however, be affected

---

[3] The reward was actually changed on the tenth day but of course did not affect the performance on that day.

[4] The term "reward-value" was borrowed from Katherine Adams Williams, 1929.

in various ways. In the first place, a further consideration of
the difference between the two groups just mentioned, after the
change of reward, indicates that the previous training may alter
the reward-value. From the tenth to the sixteenth days both
groups were rewarded with sunflower seed and yet a difference
in performance resulted which shows the altering effect of pre-
vious training. Second, it is evident that reward-value is affected
by the existing drive. That is, water has reward-value only for
the thirsty animal.

With this concept of reward-value in mind it is possible to
discuss the results of this experiment more intelligibly. The
appropriateness of reward previously mentioned is obviously
synonomous with reward-value.

It will be remembered that the animals of groups E and G
were very thirsty. It is to be expected, therefore, that their per-
formance on the water reward (days 10–18) would be equivalent.
After an initial period of becoming accustomed to the new reward
this appears to be the case.

Group G, slightly hungry and very thirsty, improved rapidly
on being changed from food to water. Group F, very hungry
and slightly thirsty, gave a corresponding deterioration in
performance.

From the results with these groups we would conclude that
maze performance is a direct function of reward-value. By
appropriately varying the component factors of reward-value,
viz., the nature of the reward, previous experience with the
reward, and the drive, it should be possible to produce any
desired proficiency of maze performance (given the same amounts
of previous experience in the maze).

With regard to the second general problem, the results sug-
gest the possibility of obtaining greater maze proficiency when
two strong drives are present although only one of these is
rewarded. If this conclusion were verified the evident explana-
tion would be in terms of the greater activity caused by the
double drive.

LITERATURE CITED

ELLIOTT, M. H.

    1928. "The effect of change of reward on the maze performance o
        rats." *Univ. Calif. Publ. Psychol.*, 4:19–30.

SIMMONS, RIETTA

    1924. "The relative effectiveness of certain incentives in animal learn
        ing." *Comparative Psychol. Monographs*, 2, no. 7.

WILLIAMS, KATHERINE ADAMS

    1929. "The reward value of a conditioned stimulus." *Univ. Calif*
        Publ. Psychol., 4:31–55.

A SELF-RECORDING MAZE WITH AN AUTOMATIC DELIVERY TABLE[1]

BY

E. C. TOLMAN, R. C. TRYON, AND L. A. JEFFRESS

The need for some form of self-recording maze, to be used in experiments in which large numbers of rats are to be run, and a description of a preliminary type of such maze were presented in a previous article.[2] The present paper describes the final form of the maze. A comparison of the two articles will indicate that the changes consist principally in: (1) the addition of an automatic delivery table upon which the animals live during the course of the experiment and which delivers them automatically, one at a time, to and from the maze, (2) the substitution of a modified recording voltmeter in place of electric counters as the device for recording errors and time, and (3) the use of mercury cup contacts under the treads in the maze floor in place of telegraph keys.

The maze as here described has been erected in the Psychology Building of the University of California and has already been used for an extended experiment upon the inheritance of maze-ability in rats.[3]   Its practicability is indicated by the fact that to date more than 10,000 single trips have been made through it and successfully recorded.

I. GENERAL PROCEDURE

Figure 1 shows the general layout of the apparatus.   A partition separates the maze room from the animal room (fig. 2). The animals to be run are placed in the revolving delivery table at the end of this room. The table has two tiers of compartments, so that each animal has an upper and a lower compartment.   He lives in the upper compartment until the time for the day's run, when he and his compartment are transferred to the lower tier. This transfer is made without handling him individually, for the compartments are in nests of seven.   These nests can be removed like bureau drawers and inserted in either the upper or lower tier.   (See fig. 3 where a lower nest of compartments in the lower tier has been partly pulled out.)   The empty compartments taken from below are put above and supplied with food.

The animal goes into the maze room at the point marked "Start" in figure 1, climbs a short incline to the level of the maze, and after one right and one left turn enters the first unit of the maze.   The maze is made up of seventeen T units, like the one shown at the bottom of figure 1.   Each unit contains a blind alley and an exit into the next unit.   The dotted line in the figure indicates the path of a rat which enters the unit at the elbow piece, walks over a trap door, *TD* (which by rising up behind him prevents his retracing), comes to the choice point, enters the blind alley, returns from it, and goes into the next unit.   Black curtains, *C*, are draped halfway in the blind and also in the true path in order that both may look alike.   All the floors are
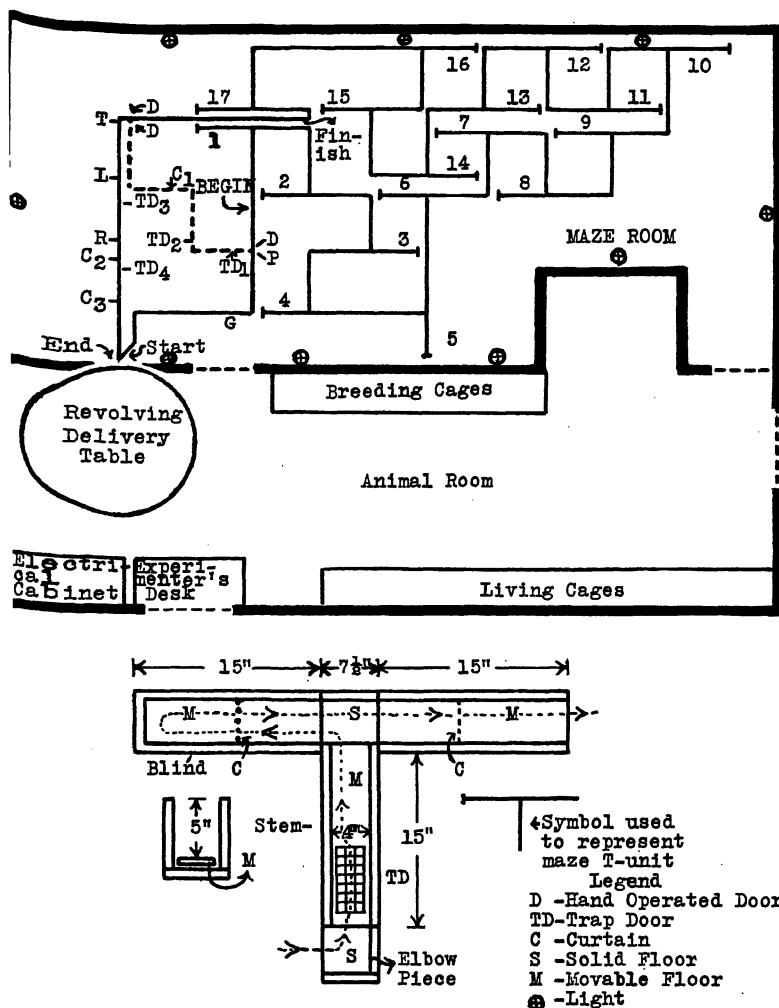
Fig. 1. Diagram showing general plan of automatic maze; a schematic presentation of the animal room and maze room. Below: sketch of a unit.

.ovable, except *S*. As the rat walks over the movable floors, ιey dip slightly into mercury cups beneath, which connect by ires to the recording device. In traversing the maze, the animal ϳes through all seventeen units, marked by numerals in figure 1,

and finally arrives at a point directly above his starting place. Here he enters his upper compartment by going through a final end-door ("End"), which, when it rises behind him, sets the revolving table automatically in motion. The table turns to bring the next compartment into position, and stops; the next animal then leaves his lower compartment to tread the maze; and so on until all the animals living on the table (a maximum of fifty-six) have been run.

Immediately before an animal enters the first unit, he walks over a floor (see "Begin" in fig. 1) which sets going the recording device at the experimenter's desk. This device registers on a tape the path of the animal through the maze, and is turned off by the animal at a point beyond the last unit (see "Finish" in fig. 1).

Figure 4 is from a photograph showing the first and last parts of the maze. The rat's progress as described above appears in part in this figure as follows: At *S* ("Start") the rat comes out of the table, then climbs up to the maze level and enters the maze proper at *B* ("Begin") where he sets going the recording device. T-unit No. 2 is in the right foreground, No. 4 is to the left in the foreground. In these units one may observe the curtains and automatic doors. When the rat has gone through all of the units, he comes out at *T* at the upper right portion of figure 4, and goes from *T* to *E* where he enters his upper compartment. In the figure a short-cut is shown, by which an animal may go from *P* directly to *T* without entering the maze proper. This short-cut is a preliminary training path which will be discussed under "Experimental technique."

After the animals have all been put into their lower compartments, before the day's run, the experimenter's presence is no longer necessary, for the animals run themselves. Ordinarily, he works at the desk shown in figure 7. Above the desk the recording device is fastened to the wall, and to the right of it is an electrical cabinet containing all of the central electrical con-
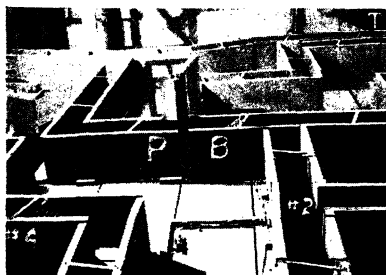
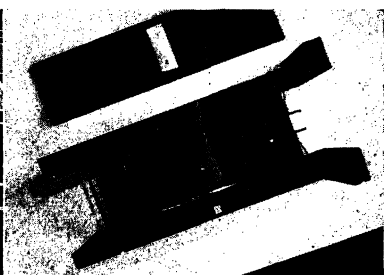Fig. 2   Fig. 3
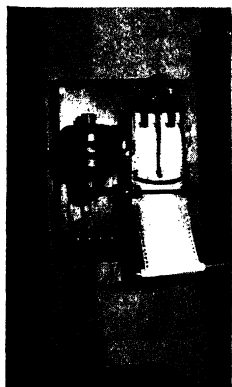
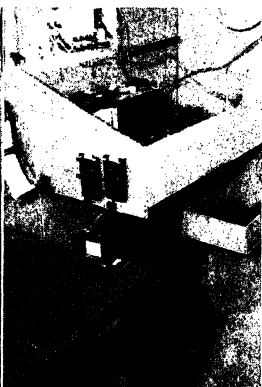

Fig. 4   Fig. 5

Fig. 6   Fig. 7   Fig. 8

Fig. 2.   Animal room.
Fig. 3.   Revolving table compartments.
Fig. 4.   Beginning of maze.
Fig. 5.   Tread.
Fig. 6.   Recording device.
Fig. 7.   Experimenter's control desk.
Fig. 8.   Table-motivating device. The spider has been lifted off its
           normal axis in this picture.

nections. Seated at his desk, the experimenter has every-thing within reach, and may control any portion of the electrical system by manipulating auxiliary hand switches.

II. TECHNICAL DETAILS

The recording device—

The automatic record involves a specially modified recording voltmeter (fig. 6). This is a "Type C" Westinghouse recording voltmeter provided by the Western Mechanical Company of Oakland, California, but modified by them to fit the special needs of the situation.

The rate of travel of the recording paper was very much speeded up by means of a small 60-cycle 110-volt A.C. fan-motor attached to the meter in place of the original motor. The increased speed was necessary to record the progress of an ordinarily fast-moving rat. The special motor speeds up the tape to 15 cm. per minute. The details of the wiring of the motor circuit are shown in figure 9. When the rat steps on the tread of the starting unit, K ("Begin," fig. 1) he thereby completes a circuit through the magnet of relay No. 3, which closes the circuit and starts the motor going. At the same time he also magnetizes relay No. 1, which shunts across this tread and keeps the circuit closed even after the rat has gone on farther. In fact, the circuit is kept closed until the rat finally steps on the finishing tread ("Finish," fig. 1). The finishing tread closes an additional circuit which magnetizes relay No. 2, and this is so wired that, when magnetized, it breaks the original circuit. Relay No. 3 is thus demagnetized and the A.C. motor circuit broken.

By specific types of deflection the recording meter shows the particular tread of the maze proper which at a given moment is occupied by a rat. Figure 5 shows the tread in the "stem" of a T-unit (see bottom of fig. 1). In the figure, the floor of the tread has been removed by simply lifting it out and it is shown lying upside down beside the frame in which it normally sits

When this floor is put back, it rests on the galvanized iron fulcrum screwed to the middle of the base of the tread. In the normal position, one of the metal prongs in one end under the surface of the floor (see figure) rests *above* the mercury, which only partly fills its cup, while the other prong is perpetually immersed in the mercury which completely fills its cup. As a rat goes over the wire door and steps on the floor, this floor dips down slightly and causes the prong which had been above the mercury to dip into its cup, thus completing a "stem" circuit. Besides this type of "stem" tread there is a "blind" tread (see fig. 1) which is identical with the "stem" except that it lacks a wire trapdoor. "Stem" and "blind" treads, however, make, as we shall see, different deflections of the recording needle. The other arms of each T unit also have treads. But these in our actual practice have not been wired (although they could be).
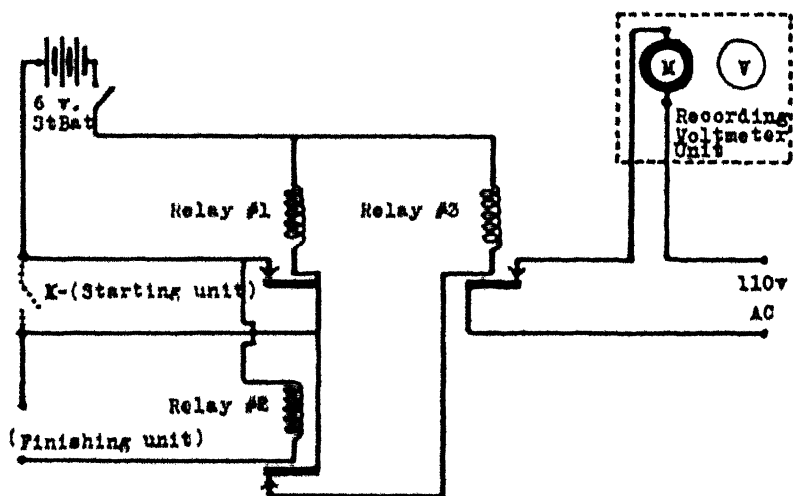
Fig. 9. Circuits to control motor on recording voltmeter.

The wire automatic doors appearing in the stem treads are simply pieces of hardware cloth hinged by nails at the bottom and held up by rubber bands. When a rat walks up on these doors they go down in front of him, because of his weight. When he has stepped off, they fly up behind him and prevent his retracing.

The meter in the recording device was rewound so as to adapt it to recording a total potential drop of only *6 v.* (that provided by an ordinary storage battery). A potentiometer wire connected across a storage battery served as the source of potential, and five different amounts of potential drop were tapped off from this wire and connected in circuit with the various types of tread. The wiring is shown in figure 10. The middle of the five
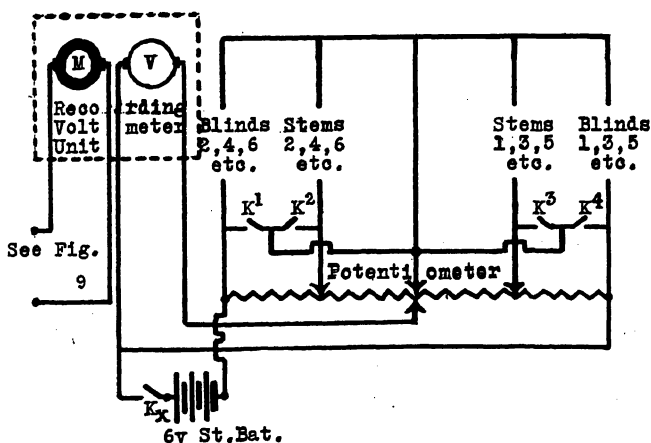

Fig. 10. Wiring of the treads to the recording needle of the voltmeter.

potential drops was used as a dead line, so that the needle would stay in the center of the recording paper when no contacts were being made in the maze. The two smaller potential drops, recording above this middle line, were wired with alternate odd units in the maze, that is, with units number 1, 3, 5, etc. And the two greater potential drops recording below this dead line were wired with the alternate even units in the maze, that is, with 2, 4, 6, etc. In this way maze unit No. 1 records to the left of the middle position of the needle; unit no. 2 to the right of this middle position; unit No. 3 to the left again; unit No. 4 to the right; and so on. Thus, by counting from the beginning of any rat's record, it is easy enough to discover in which units his errors were made. The potential nearer in value to the middle

was wired with the stem of the unit and the potential farther away from the middle was wired with the blind. K^1, K^2, K^3, K^4 are hand switches with which the experimenter may test the operation of the voltmeter without actually pressing down the corresponding treads in the maze.

A typical maze record appears on the tape as follows:
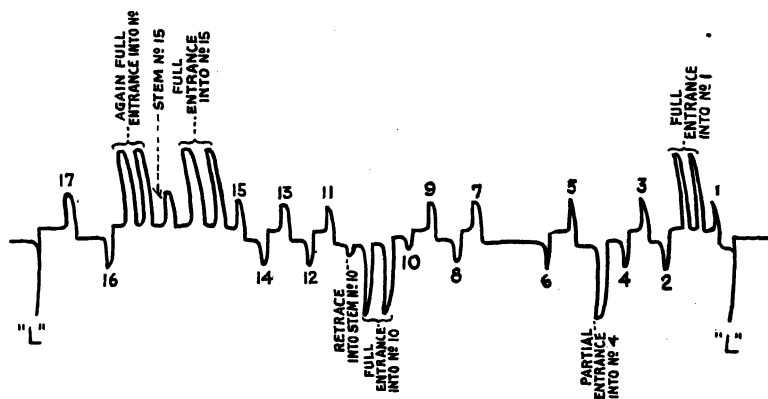
This tape illustrates how complete a score one may get of the rat's performance. Read the tape from *right to left*. After the preceding rat has turned off the recording device at "Finish," he travels around to L which is a unit wired like blinds 2, 4, 6, ... By the time he reaches L, the tape has stopped running and the deflection of L is a straight line, and hence has a different appearance from all other deflections, thus denoting the separation mark between the runs of adjacent rats. On the tape shown, the double deflection at blind No. 1 denotes a *full* entrance in the blind. When the rat first steps into blind No. 1, the floor dips into the mercury and the needle deflects. When he goes fully in, the floor dips out of one of the mercury cups and the needle returns to neutral. On coming out of the unit, the rat again depresses the floor and the second deflection occurs. The single deflection at blind No. 4 means therefore only a partial entrance. All of the short deflections represent "stems" of the

successive units as shown. At blind No. 10 is another full entrance with a retracing into the stem. The remainder of the tape is self-explanatory. Since the tape travels through the recorder at a uniform rate, the length of the tape between the two "L's" is an index of the time of the rat's run.

Motivating system for revolving table—

The rat steps off the last section of the maze upon an end-gate and then into its home cage (upper compartment) on the living
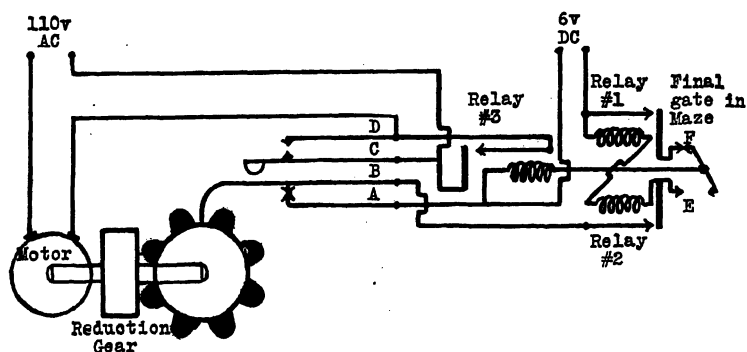

Fig. 11. Wiring of motivating system.

table. As it steps off the gate, thus allowing the latter to swing up again, the table begins to revolve very slowly by means of a motor and spider which engages pegs on the underside of the periphery of the table. (See fig. 13; also fig. 8, where a picture of the mechanical device is shown.) In this way the table is brought into position so that, when the motor stops automatically, the next rat is opposite the lower entrance leading to the maze. He enters the maze, runs through it, returns in similar manner to his upper compartment. The table starts again; and the procedure is repeated.

In order to accomplish all this, certain special features of wiring, of relays, and of specially constructed switches were necessary. First, the *end-gate,* over which the rat steps to get from the maze onto the table (fig. 14 gives a side view of this gate and its connections). This gate has a double set of mercury

contacts. In the retiring closed position a contact is made with the mercury cup *F*. In the open position, when the rat has his full weight upon the gate, a contact is made with the cup *E*. By means of a relay (see wiring diagram, fig. 11, relay No. 1), the connections are so arranged that a contact must be made first
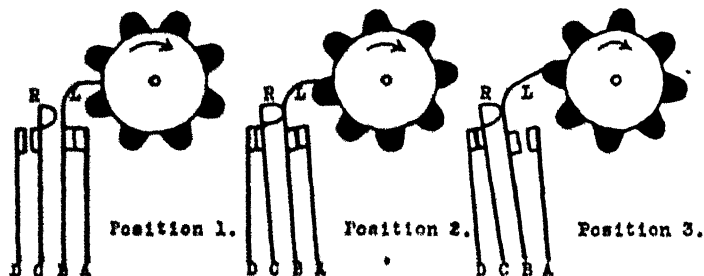

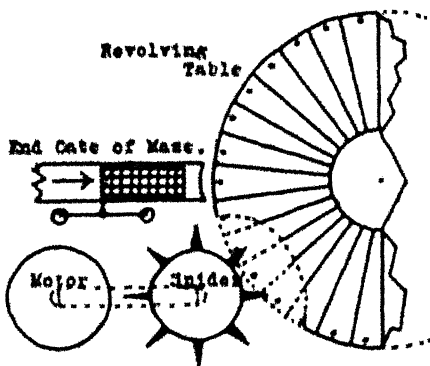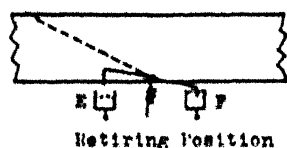Fig. 12. Special switch for operating motor.

Fig 13   Fig. 14

Fig. 13. Spider which engages pegs under floor of table.
Fig. 14. End gate in maze.

at *E* and then at *F* before the motor, which revolves the table, will start. This is to make sure that the rat has got off the gate and onto the table before the table starts moving. If, upon contact *E* alone, the table started, the animal might be caught either not on the table at all, or half on and half off.

Second, the *special switch* necessary for the motor: This switch is operated mechanically by a set of nubs upon the hub of the spider, which work in cam fashion. Figure 12 shows three

successive positions of this switch. In position 1, a contact is made through A and B. When the rat has reached his upper compartment and has made the required double contact at E and then at F, thus closing relays No. 1 and No. 2, the current passes through AB and thence to the relay No. 3 (see fig. 11). The motor starts and the table begins to turn. As the motor continues to turn, the main finger, LB, of the switch is gradually pushed to the left (fig. 12) and as a result of the hard rubber mounting, R, it gradually pushes the finger C over to the left until a contact is also made between C and D, and position 2 is reached. Contact is now established through both AB and CD. But CD is wired directly (fig. 11) with the alternating current which runs the motor, so that, as long as contact CD continues to be made, the motor will continue to be run. Position 3 (fig. 12) is next reached, and AB is opened, whereupon there fails the activation of relay No. 3, which originally started the motor when AB was closed (see fig. 11). The motor, however, continues to act because of connection CD, until position 1 is again reached, when CD is broken and the motor stops. The table is now in position for the next rat. In order that AB may start the table again, relay No. 3 has to be again activated through the contacts E and F at the end-gate.

III. SPECIAL EXPERIMENTAL TECHNIQUE

After the apparatus was constructed, it was necessary to "fit" it, as it were, to the animals. Some sixty rats were run and discarded before a satisfactory experimental technique was developed. This technique involved giving a preliminary experience, a "test-breaking" practice, to the animals. This preliminary conditioning was obtained on a path of constant length for all animals (see short-cut, P to T, in fig. 4). The rat was thus gradually acquainted with the special features of the maze so that, in the maze proper, he would not be upset by them. There was, as a result, considerable reduction in the customary "experimental mortality" (i.e., discarding of animals because of their refusal to run, an exigency which is such a discouraging feature in most

maze-running). Without such a preliminary training, it is
doubtful whether the rats would operate such an apparatus
as this. Given such training, they operated it with rapidity, and
not more than one out of fifty animals had to be discarded.

Preliminary procedure

The first day, the rat is weighed and transferred from his
living cage, in which he has been with other animals, to his upper
compartment on the revolving table. He is not given food on
this day. The next seven days are devoted to short runs through
the preliminary short cut. This path (as may be seen in fig. 1)
begins at ''Start,'' makes a right, then a left turn, and then
follows the dashed line of the diagram to its end where a 180-
degree turn occurs; then goes straight on into the upper com-
partment. This path contains movable floors, curtains, and
automatic doors as indicated. On days 2, 3, 4, and 5, the experi-
menter puts the rat by hand (two runs a day) through parts of
this path. Thus, on the second day the rat is introduced by hand
just outside the end gate (''End'') and goes through this door
into his upper compartment. The end gate is held down for him
on these two trials   On the third day the procedure is the same
but the end gate is up and the rat has to manipulate it himself.
On the fourth day, he is first put in at R, goes to T, and retraces to
''End''; on the second trip he is put in at T and goes to '' End.''
On the fifth day, he goes on the first trip from T to P and then
back to ''End''; on the second run, he goes from G back to the
''Start,'' enters his lower compartment, and then returns to
''End.''   From the sixth to the eighth days he makes complete
trips through the entire preliminary path. On the sixth day the
various trapdoors (TD) are set up. These doors are the same
as those in the maze. But up to the sixth day the rubber bands
are slipped off their retaining nails and lie flat on the floor so
that the animals merely walk over them. On the sixth day,
however, TD_4 is put up; on the seventh day, TD_3, and curtain,
C_3, are added; on the eighth day, TD_2 and TD_1, C_2 and C_1, are
added   Each day of training has thus introduced the animal to
new features. As a result, through all of the training trials, as

well as on the ninth day, when the animal first goes into the maze proper, he runs rapidly and with little upset. The animals are not handled after the fifth training day, except once for weighing on the eighth day.

On the first and second day of running in the maze proper, because of the great amount of time which the rats take to explore the various alleys, tape is usually saved by taking hand records of errors made. By the third day, the time of running is so reduced that the recording device is used. In case, however, any rat dallies thereafter, the experimenter can turn off the recording device by using the hand switch, K, (fig. 10), at his desk, and note the time with a stop watch until the animal again starts running.

Since the rat runs only once a day, the food placed in the upper compartment must, of course, contain all of the nutriment (including water) necessary to keep him in good condition during the experimental period. If it is desired to keep the rats at a uniform weight over the experimental period, they must be weighed daily, and the food regulated accordingly.

This apparatus requires but little care to keep it in order. Two storage batteries are used, one to operate the relay systems, the other the recording needle. They will carry a maximum charge indefinitely by attaching them to a Trickle charger, which is itself attached to the alternating circuit. Occasionally, the dried faeces of the rats wedge between the floor of a given unit and the frame in which it sits, thus preventing proper contacts. To avoid this difficulty, a testing stick has been devised, which has a stiff wire affixed to one end. By inserting this wire through the wire netting which covers the maze units, the rocking play of each floor and the consequent making of the correct contacts, may be tested. The recording device is started and all of the units are thus systematically tested before each day's running. This testing, with the 17 unit maze, takes less than half a minute. The mercury cups stay in good condition for at least six months. Only about twice a year are they cleansed and supplied with new mercury.

THE EFFECT OF THE INTRODUCTION
OF REWARD UPON THE MAZE
PERFORMANCE OF RATS

BY

HUGH CARLTON BLODGETT

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—George M. Stratton, Warner Brown, and Edward C. Tolman, Editors.

Price per volume, $3.50.

THE EFFECT OF THE INTRODUCTION OF REWARD UPON THE MAZE PERFORMANCE OF RATS*

BY

HUGH CARLTON BLODGETT

PROBLEM

The purpose of this investigation was to study the efficiency of units of practice when unaccompanied by reward. The method devised was that of running two groups of rats through the maze: an *experimental group* which received no reward during the first part of learning, but which suddenly had reward introduced in the latter part of learning, and a *control group* which received reward throughout the whole of learning. The answer to the question as to the efficiency of non-reward units of practice was sought in a comparison of the learning curve of the experimental group (both before and after the introduction of reward) with that of the control group.

LITERATURE

Most of the previous experimental work on rewards and their relation to learning has been concerned with a comparison of the effectiveness of different incentives as such. The incentives have been sometimes different in quality, as food and escape, and sometimes the same in quality, as two kinds of food, or two strengths of induction shock.

In addition to the general experiments indicating different strengths of reward without much attempt to analyze further what really may be involved, there are three experiments or parts of experiments strictly germane to our present study.

Lashley (1918), in a maze experiment upon distribution of practice, throws some light upon our problem. There were only 25 rats in all, divided into four groups: group A was allowed to run about in the maze for 20 minutes the day before the first run. During training, this group was given reward at the end of the run. Group B was a control, run once a day with the incentive of food; Group C was run the same as A but was not allowed to correct errors; and group D was run with the incentive of food screened in the food box. The quickest learning was made by group A, the group which explored the maze for 20 minutes before the first run. The record of the control group, group B, was next best, group C was third, and group D, last.

Szymanski (1918) has published a series of articles upon the learning of maze habits with various kinds of reward. One of his experiments is closely related to our problem. Three rats were run through a maze to their home cage in which food had been placed. The rats were not hungry. At the end of 61 trials there was no reduction in time and error scores. Then the condition of experiment was changed so that the rats were run when they were hungry. They ran the maze perfectly in one or two trials.

Simmons (1924), in an article on relative effectiveness of various incentives, ran a group of 10 animals under conditions which she designated as delayed incentive. This group was run for five days without incentive. At the beginning and the end of the sixth trial, the animals were given a taste of food, such as was given the control group. In comparing the learning curves for this group and the control group, Simmons unfortunately combined the scores of her rats in groups of five days each. It is impossible, therefore, to determine the precise nature

of the difference in the time and error scores for the two groups immediately after the incentive was given to the delayed-incentive group on the sixth day. This can be made clear by an analysis of the error curves given in her monograph.

As will be seen from the curve (fig. 1), the mean number of errors during the first five days, for the delayed group, was approximately 28 against an approximate 10 for the control group.
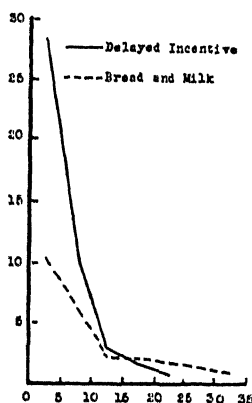
Fig. 1.

Day 6, which is averaged with four following days, was without incentive. As a result, the second point on the curve is a composite of the scores of one run which was made before incentive was introduced at the end of the run, and four runs which were made after incentive had been introduced. Obviously this procedure masks any sudden change on the run following the first reward.

Simmons then compared the total number of trials required by the control group and by the delayed-incentive group to reach the learning criterion, the total number of errors for the groups, and the total amount of time. She found that the delayed-incentive group required fewer runs but that the error score and the time score were greater. This is because the errors and time scores made during the first six runs are figured in the total.

She then made the same comparisons, leaving out the first five runs. Again she found the same results. This time, however, the superiority of the control group, in time and error scores, was less, because only one non-reward run (the sixth) was figured in the total. Finally, she compared trials, time, and errors, leaving out of account the first eight runs. In this case the delayed-incentive group reached the learning criterion in fewer trials, and made fewer errors and shorter times. This shows that a very marked change in time scores and error scores must have taken place in the delayed-incentive group between the fifth run and the eighth run. And one may assume that this change took place on the seventh run, after reward had been given at the end of the sixth run.

Attention should also be called to the fact that comparisons of scores for the latter part of the learning periods of the control group and the delayed-incentive group contain a spurious feature, namely, that practice for the two groups is not constant because of the much greater number of retracings made by the delayed incentive group during the non-reward period. And so the better final scores of the delayed-incentive group may be due to a different practice effect in the first six runs.

MATERIALS AND METHODS

Mazes.—Three mazes, A, B, and C, were used. Ground plans are shown in figures 2, 3, and 4. Maze A and maze B had ordinary blinds. Maze C was a two-way maze presenting as alternatives a long and a short path to food.

All three mazes contained a feature not hitherto used in mazes. At each choice point, doors were installed which could be closed behind the animal. These doors were hinged at the top and, when open, lay along the top of the alley. They prevented retracings from one section of the maze to another, they were noiseless, and they caused no excitement in the animals. Their positions in the mazes are shown by the dotted lines, *D*.
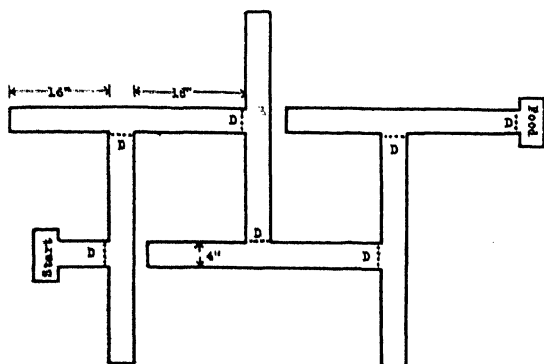
Maze A

Fig. 2.
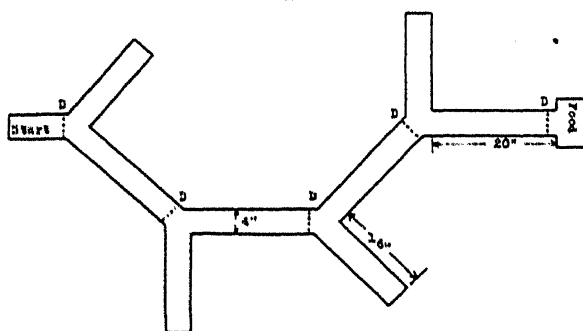
Maze B

Fig. 3.
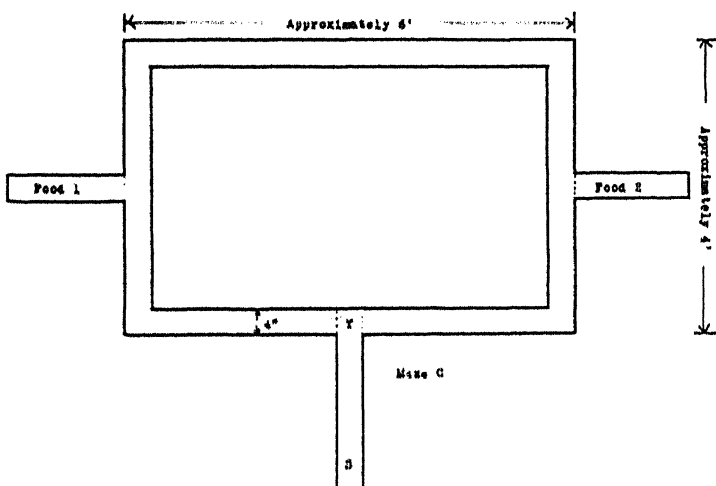
Maze C

Fig. 4.

The value of this feature is fourfold: (1) it reduces the time of the experiment; (2) it standardizes each run by preventing the rat from running through the maze several times before entering the food box; (3) it equalizes practice in different parts of the maze; (4) it tends to cause a more symmetrical distribution curve of errors for a group of animals. For retracing tends, as such, to give some unduly large scores.

It may perhaps be argued that this introduction of doors was unsound because it introduced an artificial limit into the problem. Every experiment is necessarily artificial. Thus, for example, in the ordinary maze, the experimenter "artificially" excludes certain "normal" cues as, for example, odors and distinguishing tactual factors. All that has been done, in this case, is to restrict our conclusions to types of maze which do not allow retracings.

A second feature of importance which holds for mazes A and B is the fact that all the blind alleys in the same maze have the same dimensions and the same angular relationships to the true path. This is believed to be an improvement over the usual maze, in that the error scores (number of entrances into blinds) are more definitely scaled.

The mazes were constructed of wood painted dark brown. The walls were 8 inches high and $\frac{7}{8}$ inch thick. The tops of the alleys were covered with $\frac{1}{4}$ inch mesh wire screen. The alleys had no permanent bottom but were placed on a heavy piece of linoleum. The wire covers and the linoleum were painted the same color as the sides.

Animals.—The rats were of mixed strain, black and white. They were raised, four to six in a group, in wire cages 10 × 14 inches in a room varying in temperature from 55 to 85 degrees Fahrenheit. They were accustomed to occasional handling at feeding time and when their cages were cleaned, and so they were not wild. They were approximately three months of age when the experiment was begun. The number of males and females was nearly even.

Food.—Their food during the pre-experimental stage consisted of a mash of ground barley, bran, and table scraps. Beginning three days before the experiment and throughout the experimental period the animals were fed approximately one-tenth their weight of food saturated with water. They were given no other water. The food was a mixture of four parts dry bread, ground up in fine bits, one part bran, one part sunflower seed, and three-fourths part powdered skim milk.

Scoring.—With mazes A and B, a rat was counted as having made one error if it made one (or more) entrances of as much as a body's length (not counting tail) into a blind, while in a given segment of the maze. That is, even though the rat entered and reëntered a given blind before passing to the next segment, it was counted as having made only *one* error.

In maze C a rat was counted as having made one error whenever it took the long path rather than the short path to the food box.

Time was measured by a stopwatch, in seconds from the time the rat left the starting box until the door of the food box was closed behind it.

PROCEDURE AND RESULTS

Maze A: Groups I, II, and III

Group I. *Control.*—This group consisted of 36 rats run once a day for seven days and allowed to eat for *three minutes in the food box at the end of each run.* They were then removed to another cage (not the living cage) and allowed to finish their day's ration, after which they were returned to their living-cages.

Group II. *Experimental.*—This group also consisted of 36 rats. (They were litter mates of group I. Of each original litter, half the number were put in group I, and half in group II.) *For the first six days,* group II found no food in the food box and were kept in it without reward for two minutes.

They were then removed to another cage (not the living-c
where they were fed after an interval of approximately
hour. Only then were they returned to their living-c
For day seven and the two subsequent days they were tr
exactly like group I; that is, they found food in the food
for three minutes and finished their day's ration immedi
afterward in another cage.
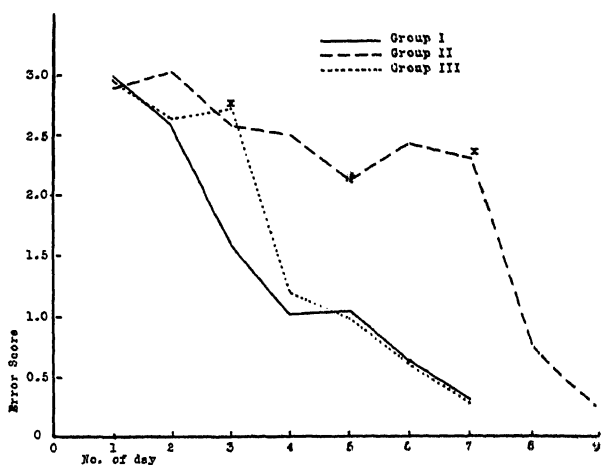
Fig. 5.

Group III. *Experimental.*—This group consisted of 25
Like group II, they began with no reward at the end of the n
But for them such reward was introduced at the end of
third day rather than at the end of the seventh day.

Figures 5 and 6 present the error curves and the time cu
for each of these three groups. And tables 1 and 2 indicate
differences and the reliability of these differences between
three curves on each successive day.

Examining the error curves and tables, two points app.

1. The experimental groups (II and III), so long as
were *without reward*, did very much worse than the con
group (I). In fact, the curves for groups II and III st
almost horizontal until after the day (indicated by the cr
when food was introduced.

2. On the day after this first reward (i.e., on day 8 for group II and on day 4 for group III), errors dropped greatly. And on the second day after reward (i.e., on day 9 for group II and on day 5 for group III) the curves had dropped almost to the level of the curve for the control group.
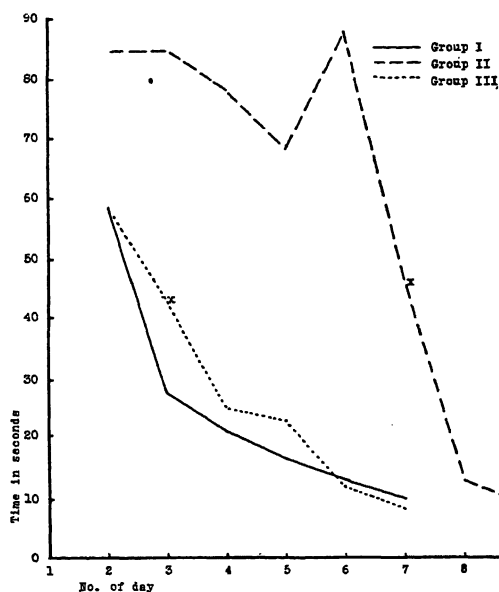
Fig. 6.

Examining the time curves and tables, a similar picture appears, save that in the case of time the sudden drops seem to have come on the day of the introduction of the reward rather than on the day after. It appears, in other words, that, although the rats had not yet, on that day, actually experienced the finding of the food, their times were shortened by the fact of its presence in the food box (though their errors, as has been seen, were not reduced). The explanation which suggests itself is that the odor of the food caused greater general activity and hence a shorter running time although it did not cause fewer errors. (For the rats had yet to learn *just where* the food was.)

A further question now arises. Do these sudden drops in errors which come after the introduction of reward indicate that something to be called a *latent learning* developed during the non-reward period—a latent learning which made itself manifest after the reward had been presented? Obviously, if this is to be answered in the affirmative, one must show that the drops which occurred immediately subsequent to the reward were larger than "normal," that is, that they were bigger than drops in the control curve.

TABLE 1

MEAN ERRORS

Day	Group I	Group II	Group III	Group II–Group I			Group III–Group I		
				Diff.	σ Diff.	Critical ratio	Diff.	σ Diff.	Critical ratio
1	2.97	2.89	2.96	−.08	.23	.35	−.01	.28	.04
2	2.56	3.03	2.64	.47	.28	1.66	.08	.30	.28
3	1.58	2.56	2.72	.97	.28	3.48	1.14	.27	4.27
4	1.03	2.47	1.20	1.44	.26	5.62	.17	.24	.71
5	1.08	2.08	.96	1.00	.24	4.26	.12	.30	.41
6	.69	2.42	.60	1.72	.28	6.17	.09	.20	.47
7	.30	2.28	.28	1.97	.20	12.72	.02	.13	.19
8	....	.86	....	....	....	....	....	....	....
9	....	.25	....	....	....	....	....	....	....

TABLE 2

TIME (SECONDS)

Day	Group I	Group II	Group III	Group II–Group I			Group III–Group I		
				Diff.	σ Diff.	Critical ratio	Diff.	σ Diff.	Critical ratio
2	58.19	84.58	57.60	26.39	10.42	2.53	.59	7.38	.08
3	27.50	84.86	42.60	57.36	19.73	2.91	15.10	3.11	4.86
4	21.39	77.72	25.44	56.34	14.53	3.88	4.05	5.15	.79
5	16.22	67.64	23.32	51.42	8.54	6.02	7.10	5.07	1.40
6	13.06	87.22	12.76	73.97	19.20	3.85	.30	1.77	.17
7	9.97	46.70	8.84	36.72	4.04	9.09	1.13	1.07	1.06
8	....	12.46	....	....	....	....	....	....	....
9	....	8.61	....	....	....	....	....	....	....

The first way of checking this was to compare the drops made by group II between days 7 and 8 and by group III between days 3 and 4 with the *largest* drop made by group I between any two days, which latter (see fig. 5) was obviously between days 2 and 3.

The results of this comparison are shown in table 3.

TABLE 3

MEAN ERRORS

	Drop in errors	Difference between drop and that shown in Group I	σ Difference	Critical ratio
Group I—Days 2–3	.972			
Group II—Days 7–8	1.416	.444	.332	1.338
Group III—Days 3–4	1.520	.548	.355	1.544

The critical ratio of 1.338 when interpreted in terms of probability means that if there were no real difference between the drops shown by group II, days 7–8, and that shown by group I, days 2–3, a difference between these two drops as large as that obtained and shown in the table would occur by chance 904 times out of 10,000, or a little less than one-tenth of the time. It therefore seems probable, although not certain, that group II dropped more on this day than did group I (control) on the day of its greatest drop.

Similarly, the critical ratio of 1.544, when interpreted in terms of probability, means that, if there were no real difference between the drop shown by group III, days 3–4, and that shown by group I, days 2–3, a difference as large as that shown in the table would occur by chance 612 times out of 10,000, or between one-fifteenth and one-sixteenth of the time. It again, therefore, seems probable, although not certain, that group III dropped more on this day than did group I on the day of its greatest drop.

Taking these two results together, the hypothesis that the periods of non-reward in groups II and III really produced

latent learning which became manifest when a reward was introduced seems well supported.

A second way, however, of testing the validity of this hypothesis is suggested. It appears that it might be fair to compare the drops in group II and III not with the one biggest actual drop made anywhere by group I, but rather with the interpolated drops made by group I from the *levels* corresponding to those from which the drops in groups II and III begin. In order to obtain these, an interpolative procedure was required. This (in the case of group II) was as follows: in figure 5 a horizontal was drawn to the left from the point on curve II corresponding to day 7, until this horizontal intersected curve I. A vertical was then dropped from this intersection to the X-axis. And a distance was thence measured off to the right, equal to the unit of one day. Another vertical was erected from this new point until curve I was again intersected, and the vertical distance between the two intersections on curve I was taken as the demanded drop. A similar procedure was followed with respect to group III.

Finally, however, in order to compare these interpolated drops on curve I and the corresponding drops on curves II and III, it was found necessary to estimate sigmas for the interpolated drops. The sigmas obtained for the actually measured drops on curve I, that is, for the drops between days 1–2, 2–3, 3–4, 4–5, 5–6, 6–7, were as follows: .237, .239, .247, .228, .190, and .187. It would seem, therefore, that to assume a sigma of .275 for an interpolated drop is more than fair.

Comparing, now, the drops in group II, days 7–8, and in group III, days 3–4, with the interpolated drops in group I corresponding to them, we have the results shown in table 4.

The critical ratio of 1.497, when interpreted in terms of probability, means that, if there were no real difference between the drop shown by group II, days 7–8, and that interpolated on the same level in group I, a difference as large as that shown in the table would occur by chance 671 times out of 10,000. This

again suggests rather strongly that the drop between days 7–8 in group II is really greater than any corresponding drop in group I. It suggests, in short, that the drop between days 7–8 was evidence of a real *latent* learning which had already developed and was here being brought to light by the introduction of the reward.

TABLE 4

MEAN ERRORS

	Drop in errors	σ Drop	Difference between drop and that of Group I	σ Difference	Critical ratio
Group II—days 7–8..........	1.416	.232	....	....	....
Group I—interpolated....	.877	.275	.539	.360	1.497
Group III—days 3–4........	1.520	.263	....	....	....
Group I—interpolated....	.740	.275	.780	.381	2.047

Similarly, the critical ratio, 2.047, when interpreted in terms of probability, means that, if there were no real difference between the drop shown by group III, days 3–4, and that interpolated at the same level of the curve for group I, a difference as large as that shown in the table would occur by chance only 173 times out of 10,000. This is a very strong indication that the drop between days 3–4 was evidence of a true latent learning having occurred in group III which was brought to light by the introduction of the reward.

MAZE B: GROUPS I AND II

To make sure that the differences just discussed were not due to any differences between the two groups arising from sampling, one of our experimental groups and the control group were tested in a second maze.

Thus, 22 rats of group II and 23 rats from group I were, subsequent to their practice in maze A, run in maze B. Both groups were run once a day and given food for two minutes in

the food box at the end of each run. The learning curves are shown in figure 7, and are practically identical. We conclude that the differences in the groups in maze A were due to the *experimental conditions* and not to native differences between the groups.
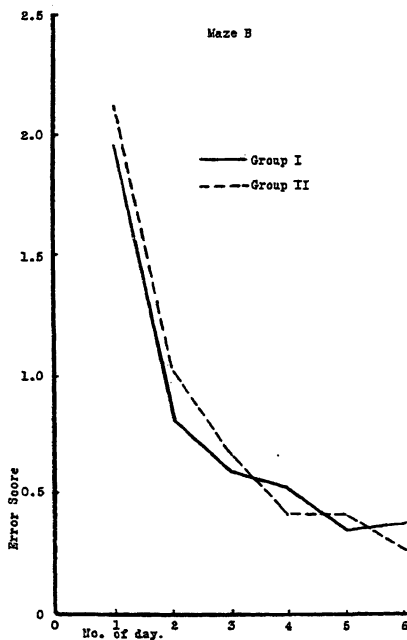

Fig. 7.

MAZE A: GROUP IV

Granted that the results so far discussed indicate that groups II and III acquired a latent learning during their non-reward periods which was made manifest when reward was introduced, questions still remain as to the nature of this latent learning. Was it the acquisition of mere general familiarity with the maze? Or was it the acquisition of a something more specific? To throw some light on these questions a fourth group of rats was run in maze A, viz., group IV.

Group IV consisted of 10 rats. Like group II, they were run for seven days without reward and then reward was introduced. But instead of being run during the non-reward period in the forward direction, they were, during this period, run in a *reverse direction*. That is, they were started at the food box (in this case empty, of course) and run to the starting box, where they received no reward. On the eighth day, their direction was changed to the *normal one* and they were given reward in the food box, as with group I. The hypothesis was that, if, upon being reversed to the normal direction and given reward, they then did decidedly better than the control group, it would suggest that the latent learning which showed itself in groups II and III upon reward may have been no more than a mere general familiarity which might have been acquired just as well through running the maze in the backward direction. If, on the contrary, they did *not* do decidedly better than the control, group I, when being run in the normal fashion, this would suggest that the latent learning developed by groups II and III was in part at least something more specific; something which could be developed only by the forward-going practice.

Table 5 gives the results of comparing errors for group IV (when running in the forward direction) with those for group I. Figure 8 gives the corresponding curves for group IV and group I, and for group II (after reward had been introduced).

TABLE 5

MEAN ERRORS

Day	Group I	Day	Group IV	Difference	σ Difference	Critical ratio
1	2 97	8	2 80	17	46	37
2	2 56	9	1 80	76	46	1 65
3	1 58	10	1 40	18	27	68
4	1 03	11	1 10	07	38	19
5	1 08	12	1 10	02	28	06
6	89	13	50	19	27	70
7	30	14	30	005	17	03

It would appear that day 2 is the only one on which there
is any significant superiority of group IV over group I.   On
that day the critical ratio of the difference in favor of group IV
is 1.647.   This, interpreted in terms of probability, means that,
if there were no real difference between the groups, a difference
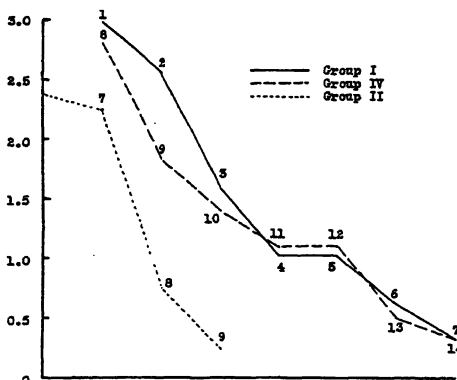as great as the one obtained would occur by chance 498 times
out of 10,000.

Fig. 8.   The point of origin for the abscissae is different for each curve.
The numeral beside each point indicates the corresponding number of the
day.

One is therefore led to conclude that the increased familiarity
with the maze gained by group IV in running backward prob-
ably did help to a *slight* extent on the second day of forward
running.   That is, group IV were somewhat better able than
group I (probably because less distracted) to make use of their
first day's experience in the forward direction. This superiority,
however, did not persist.   The initial advantage of familiarity
possessed by group IV had disappeared on the third day, when
their record was no better than that of group I.

Compare, now, in figure 8,[1] group IV with group II after
the latter were rewarded.   Group IV ran the maze for seven
days without the ''expectation'' of reward in the backward

_____

[1] A comparison in terms of sigmas of the differences and critical ratios
of the differences indicated in the figure was not presented in the table
because at the time this final report was written, the original data for
making such a comparison were no longer available.

direction. Group II ran it for seven days without the "expectation" of reward in the forward direction. Comparing day 8 of group IV with day 7 of group II, it seems evident that the non-reward forward-running is the more helpful.[2] Six days of it is more valuable than seven days of backward-running. Further, not only does the non-reward forward-running give group II a decided head-start over group IV (which had had only backward non-reward running), but it also seems to cause them to continue to learn faster. In only two days group II accomplished an error elimination which it took group IV six days to achieve. Evidently the latent learning which group II developed as a result of their non-reward forward-running was decidedly more than the *general familiarity* which group IV seems to have acquired from their non-reward backward-running.

CONCLUSIONS

1. Non-reward running definitely develops a *latent learning*, and such latent learning is made manifest when reward is introduced.

2. Furthermore, it is evident that this latent learning is something more than a general familiarity such as might be acquired by backward-running through the maze.

THE TWO-WAY MAZE

A further question now arises. Given this latent learning, what are the laws of its acquisition? There is a well-known doctrine of animal trial-and-error learning, viz., that the selection of the right path is either wholly[1] or in large part[1] dependent upon a greater frequency or recency of exercise upon the correct path than upon any one of the incorrect paths. Watson has also

---

[2] Although, as just mentioned, we have not the critical ratio for the difference.

[3] This is, or was, Watson's (1914) contention.

[4] This is one way in which Thorndike's (1911) familiar law of exercise is frequently interpreted.

attempted to show that the situation in the ordinary maze is such as, by chance, to cause the animals to have greater frequencies and recencies upon the segments of the true path than upon the blinds.

It seemed worth while, therefore, to try a different type of maze—a maze, that is, which could not, by the most strained interpretation, be supposed to give, as a result of *chance*, any greater exercise on the correct path than on the incorrect path. Such a maze is maze C (see fig. 4).[5] We now turn to the conditions and results for maze C.

MAZE C: GROUPS V AND VI

Two groups of rats were run on maze C as follows:

Group V. *Control.*—This group consisted of 23 rats. They were run once a day for sixteen days. They were allowed to eat for *two minutes in the food box* and were then removed to another cage (not their living-cages) and allowed to finish their day's ration, after which they were returned to their living cages.

Group VI. *Experimental.*—This group consisted of 21 rats (litter mates of those in group V). For the first sixteen days, they found no food in the food box but were kept in it without reward for two minutes. They were then removed to another cage (not the living-cage) where they were fed after an interval of approximately one hour. Only then were they finally returned to their living-cages. At the end of the sixteenth day's run and on the runs on the four successive days, food was given in the food box in the same manner as with group V.

For about half the animals in each group, food box 1 on the left (see fig. 4) was used. And for the other half, food box 2 on the right was used. This was to eliminate so far as possible the effects of odor and tracking.

---

[5] This fact, that mazes such as C, which present alternative correct paths (one better than the other) rather than a correct path and blinds, do not, through the laws of chance, offer any greater frequency of exercise upon the finally chosen path than upon the finally discarded path, has been previously pointed out by Kuo (1922) and by Sams and Tolman (1925).

ᵒring.—When a rat had passed the bifurcation into either
ᵒrter or the longer alley, the trapdoor was closed and he
ᵒred as having chosen either "long" or "short." His
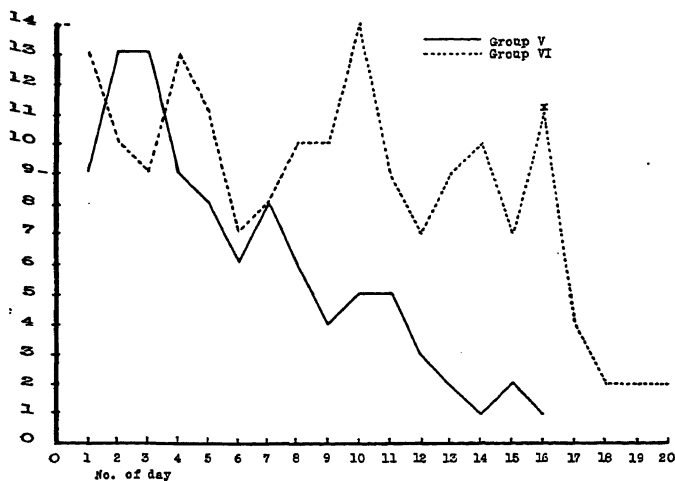ᵒm the starting box to the food box was measured by a
atch.

Fig. 9.

ᵉ results, in terms of numbers of "long" choices made by
ᵒup as a whole, are shown in tables 6 and 7 and in figure 9.
indicate a gradual improvement for the control group but
ttle improvement in the experimental group until reward
ven, and then a very sudden improvement. That is, the
l character of the results obtained with maze A were
ntiated.

rthermore, as table 8 shows, there was very little greater
ag of the short path by the experimental group until after
ward was introduced. In other words, the latent pro-
y of group VI to take the shorter route, which was made
est as soon as reward was introduced, was developed in
urse of exercise which only slightly (if at all) favored this
r route. It seems evident that the practice which devel-
latent learning did not achieve this latent learning by
of the action of selective frequency.

TABLE 6
IMPROVEMENT OF SCORES BY GROUP V

Number of run	Number of "long" choices	Chance score	Difference	σ Difference	Critical ratio
1	10	11.5	1.5	3.38	.44
2	13	11.5	1.5	3.38	.44
3	13	11.5	1.5	3.38	.44
4	9	11.5	2.5	3.35	.75
5	8	11.5	3.5	3.31	1.06
6	6	11.5	5.5	3.19	1.72
7	8	11.5	3.5	3.31	1.06
8	6	11.5	5.5	3.19	1.72
9	4	11.5	7.5	3.01	2.49
10	5	11.5	6.5	3.11	2.09
11	5	11.5	6.5	3.11	2.09
12	3	11.5	8.5	2.89	2.94
13	2	11.5	9.5	2.75	3.45
14	1	11.5	10.5	2.59	4.05
15	2	11.5	9.5	2.75	3.45
16	1	11.5	10.5	2.59	4.05

TABLE 7
IMPROVEMENT OF SCORES BY GROUP VI

Number of run	Number of "long" choices	Chance score	Difference	σ Difference	Critical ratio
1	13	10.5	+2.5	3.20	.78
2	10	10.5	− .5	3.24	.15
3	9	10.5	−1.5	3.22	.46
4	13	10.5	+2.5	3.20	.78
5	11	10.5	+ .5	3.24	.15
6	7	10.5	−3.5	3.15	1.11
7	8	10.5	−2.5	3.20	.78
8	10	10.5	− .5	3.24	.15
9	10	10.5	− .5	3.24	.15
10	14	10.5	+3.5	3.15	1.11
11	9	10.5	−1.5	3.22	.46
12	7	10.5	−3.5	3.15	1.11
13	9	10.5	−1.5	3.22	.46
14	10	10.5	+ .5	3.24	.15
15	7	10.5	−3.5	3.15	1.11
16	11	10.5	+ .5	3.24	.15
17	4	10.5	+6.5	2.90	2.24
18	2	10.5	+8.5	2.66	3.20
19	2	10.5	+8.5	2.66	3.20
20	2	10.5	+8.5	2.66	3.20

SUMMARY

1. Rats run under a non-reward condition learned much more slowly than rats run under a reward condition. This held for both errors and time.

2. Rats previously run under a non-reward condition, when suddenly rewarded made a great improvement. On the first day after the introduction of the reward their drop in mean error was greater than that made by the control group on any single day.

3. This fact seems to indicate that, during the non-reward period, the rats were developing a *latent* learning of the maze which they were able to utilize as soon as reward was introduced.

4. This latent learning, however, was something more than a general familiarity with the maze such as might be acquired by running through it in a backward direction. For a group of rats run through backward under non-reward conditions did not show any such improvement when run through in the forward direction and rewarded.

5. It was demonstrated by the use of the two-path maze that the latent learning which was developed under non-reward conditions and was made manifest as soon as reward was introduced was not the result of any very consistently greater frequency of the correct over the incorrect path during the non-reward period. It resulted, that is, from a non-reward practice which favored, almost equally, both the "incorrect" and the "correct" path.

LITERATURE CITED

KUO, Z. Y.
  1922. "The Nature of Unsuccessful Acts and their Order of Elim
    ination in Animal Learning." *Jour. Comp. Psychol.*, 2:1–27.

LASHLEY, K. S.
  1918. "A Simple Maze: with Data on the Relation of the Distribution
    of Practice to the Rate of Learning." *Psychobiology*, 1:
    353–367.

PETERSON, JOSEPH
  1918. "Effect of Length of Blind Alleys on Maze Learning." *Behav.
    Monogr.*, 3:1–53.

SAMS, C. F., and TOLMAN, E. C.
  1925. "Time Discrimination in White Rats." *Jour. Comp. Psychol.*,
    5:225–264.

SIMMONS, R.
  1924. "The Relative Effectiveness of Certain Incentives in Animal
    Learning." *Comp. Psychol. Mon.*, 2:1–79.

SZYMANSKI, J. S.
  1918. "Versuche über die Wirkung der Faktoren, die als Antrieb zum
    Erlernen einer Handlung dienen können." *Pflüger's Archiv
    f. d. gesamte Physiologie*, 171:374–385.

THORNDIKE, E. L.
  1911. *Animal Intelligence*, p. 244.

WATSON, J. B.
  1914. *Behavior*, chap. vii.

A FURTHER STUDY IN
DISCRIMINATION OF MAZE PATTERNS
BY THE RAT

BY

JOSEPH G. YOSHIOKA

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—George M. Stratton, Warner Brown, and Edward C. Tolman, Editors.
Price per volume, $3.50.

A FURTHER STUDY IN DISCRIMINATION OF MAZE PATTERNS BY THE RAT

BY

JOSEPH G. YOSHIOKA

CONTENTS

INTRODUCTION[1]

In a preliminary study in discrimination of maze patterns, the writer[2] found that the rat was able to discriminate two maze patterns, and preferred a pentagon to an equilateral triangle of equal length. Why the rat did so is the next question to be answered. The present study was undertaken in order to find an answer.

THE PROBLEM

In order to find out why the rat preferred the pentagon to the triangle a further question suggested itself. What patterns other than an irregular pentagon will the rat discriminate from and prefer to an equilateral triangle of the same length? The following experiments attempt an answer to this latter question.

APPARATUS AND METHOD

Maze

The same maze as in the preliminary study (*op. cit.*, p. 4, fig. 1) was used with modifications. Because any pair of paths offered for choice should be of equal length, the possible modifications were limited. The patterns shown in figures 1–7, however, fulfilled this requirement: an equilateral triangle; an irregular pentagon formed by joining the three midpoints of the three sides of the triangle (it stands on the same base as the triangle, and is composed of two equal equilateral triangles of one-fourth of the area) ; an irregular nonagon formed by joining consecutively the six midpoints of three sides of each of the two equilateral triangles forming the pentagon (it stands on the same base as the triangle, and is composed of four equal equilateral triangles of one-eighth of the area) ; an irregular heptadecagon formed by joining consecutively the twelve midpoints of three sides of each of the four equilateral triangles forming the nonagon (it stands on the same base as the triangle, and is composed of eight equal triangles of one-sixteenth of the area) ; an irregular pentagon No. 2 formed by cutting a little notch, 10 inches deep, at one vertex of the triangle. In each pair a more complicated path is inscribed within a simpler one, and the beginning of the inscribed path lies on the right side. As in the case of the pentagon in the preliminary study, the inscribed paths, having more turns, tended to be shorter because each turn in the inside path saved the distance of eight inches for the rat, that is, the width of two paths. To minimize this shortening, the- turning points of the inscribed paths (midpoints of the sides), as before, were shifted far enough toward the apex to lengthen the inside paths to match the outer ones.

Fig. 1
3 vs. 3

Fig. 2
3 vs. 5

Fig. 3
3 vs. 9

Fig. 4
5 vs. 9

Fig. 5
3 vs. 17

Fig. 6
5 vs. 17

Fig. 7
3 vs. 5 #2
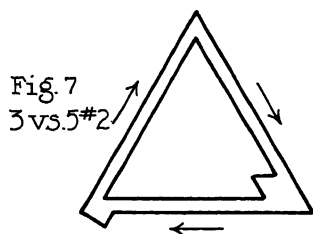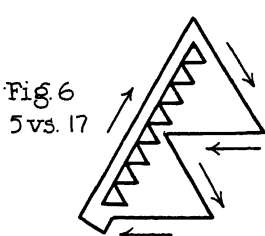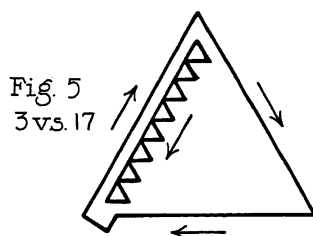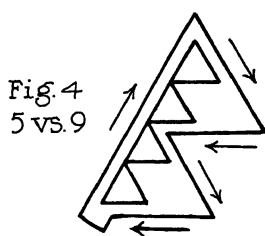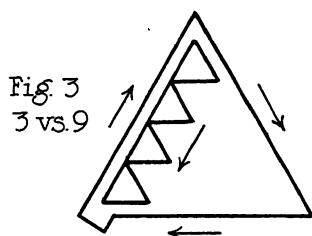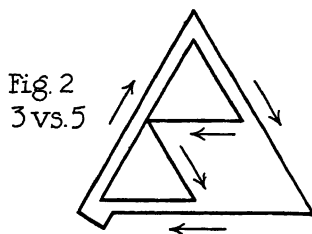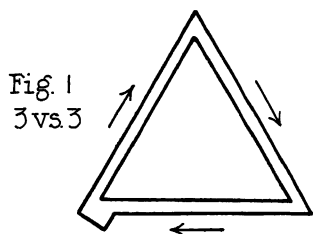
Experimental Procedure

The procedure was that followed in the preliminary study except that in the choice series the *daily-practice-method* was exclusively used. In the preliminary period the rats were given forced running through each of the two paths alternately three times daily for four days. Each path was thus run twelve times. After this preliminary training each rat was given free choice of the two paths six times daily for ten days; that is, sixty choices in all, by the *daily-practice-method*. This latter method (see the preliminary study) consisted in forcing the rat through each path once just before the daily free choice schedule. In the preliminary study this method was found to be a superior one to bring out true discriminatory propensities. The short forced daily exercise seemed to remind the rats of the characteristics of the two paths, and thus helped them to discriminate between them. The scores were the frequencies of the choices of each path within the total choices of sixty.

The experiment was carried out in the academic year of 1927–1928 in the Psychological Laboratory at the University of California. The rats were descendants from the stock of the Wistar Institute, reared in the laboratory or in the department of anatomy. At the beginning of the experiment they were five to six months old. Only male rats were used. Nine experiments were carried out, each experiment using thirty rats, except experiment VIII, in which 157 rats were used. The experiments I–VII required a new group of thirty each; the group of thirty used in experiment I was later incorporated in the group of 157 in experiment VIII; a group of thirty used in experiment IX was selected from 157 in experiment VIII. The total number of the rats used was 237.

EXPERIMENTS AND RESULTS

EXPERIMENT I: THREE VERSUS THREE SIDES

In looking over the results of the preliminary study one observes that the preferred path, the pentagon, begins on the right side. Perhaps in the majority of rats a mere position-habit of going toward the right may have resulted in the preference for the pentagon as shown by the group means. To allay this reasonable suspicion experiment I was carried out. In it the two paths offered for choice were parallel equilateral triangles, one running alongside the other all the way through (fig. 1). Theoretically there should be no discrimination; each path should by chance be taken just as often as the other. This prediction was verified. The mean frequency of the choice by thirty rats of the right triangular path in sixty choices for each was found to be 29.13 ± 2.57 (table 1). It is a close approximation to the theoretical mean of thirty. The reliability coefficient obtained by correlating the odd days with the even days was .95;[3] that obtained by correlating the first half of the days with the second half of the days was .77. Within the first and last halves the coefficients were .89 and .93, respectively, by the odd-*vs.*-even method. The intercorrelations were fairly high throughout.

Where there was no difference in pattern and length between the two paths, the rats, considering the group as a whole, failed to discriminate them. Hence the preference for the pentagon shown in the preliminary study could not have been due to a mere position habit of going toward the right.

[3] This reliability coefficient and others that will be cited hereafter are the corrected coefficients by Brown's formula. The reliability coefficients are given in full in table 2; the intercorrelations in table 3. No further reference to these will be made except where an argument needs their support.

EXPERIMENT II: THREE VERSUS FIVE SIDES

Another thing that one notes, in analyzing the two patterns (triangle and pentagon) in the preliminary study, is the positions of the first turns of the two paths. As shown in the figure of the maze, the two paths start parallel one to the other, and the pentagon diverges from the triangle at the midpoint of the first side (side *a*). Hence in tracking the pentagonal path a rat makes the first turn directed toward the food box half a side sooner than it does when it follows the triangular path. This "quicker" orientation may have entered into the preference for the pentagon. If so, a shift of the position of this diverging point of the pentagon should influence the preference.

In this experiment the diverging point of the pentagon from the triangle was placed on the second side, that is, farther away from the starting box (fig. 2). Under this condition the rats had to run along a side and a half before the pentagon diverges from the triangle, and so if the diverging point had something to do with the choice, it would presumably be more difficult to discriminate such a pentagon from the triangle. The result showed that the mean frequency of the choice of the pentagon by thirty rats in the total choices of sixty for each was 36.37 ± 2.33. The difference between this mean and the theoretical mean of 30 ± 3.87 is 6.36, 1.41 times the sigma of the difference, a fairly significant difference in favor of the pentagon (table 1). Compared with the results in the preliminary study the critical ratio dropped. Hence in discriminating the pentagon from the triangle the rats seem to have depended upon the position of the first diverging point of the pentagon. But is this point the only cue? If so, a shift of this diverging point should result in a corresponding change in the degree of preference, even when the pattern is modified. In other words, the discrimination so far observed is more a function of the diverging point than a function of the pattern as a whole. The next experiment is a test of the point just raised.

EXPERIMENT III: THREE VERSUS NINE SIDES

The rats in this experiment were made to choose between the the triangle and the nonagon. The first diverging point of the nonagon (fig. 3) is located on the second side of the triangle, one quarter of the length of a side closer to the starting box than that of the pentagon, and the number of turns in the nonagon is twice as many as in the pentagon. If the first diverging point of the complex pattern is the only determining factor for the choice of the latter, the nonagon in this case would be preferred to the triangle to a greater degree than the pentagon. The result showed that the mean frequency of the choice of the nonagon by thirty rats in the total choices of sixty for each was 37.67 ± 2.60, 7.67 above the theoretical mean of thirty (table 1). The difference is 1.64 times the sigma of the difference.

Between the two critical ratios, 1.41 and 1.64 in experiments II and III, respectively, there is no significant difference. In other words, the nonagon was no more preferred to the triangle than the pentagon to the triangle. The first diverging point of the nonagon, however, was one-quarter of the length of a side of the triangle closer to the starting box than that of the pentagon. Perhaps the shift of the diverging point was not large enough to result in a greater difference in preference in these two cases, or else the two patterns, the pentagon and the nonagon, are too complex for the rats to discriminate one from the other. The next experiment is a test of the second hypothesis.

EXPERIMENT IV: FIVE VERSUS NINE SIDES

The rats were made to choose between the pentagon and the nonagon (fig. 4). It is found that the mean frequency of the choice of the nonagon by thirty rats in the total choices of sixty for each was 30.33 ± 2.89 (table 1). This much might be expected by chance.

The rats failed in discrimination between the pentagon and the nonagon. This failure points toward the existence of a threshold in discrimination of maze patterns. An increase in complexity in patterns beyond a certain point results in failure of discrimination. To be sure of this statement and also to see the effect of a greater shift of the diverging point, the next experiment was carried out, in which a more complex pattern with the diverging point closer to the starting box was offered for choice.

EXPERIMENT V: THREE VERSUS SEVENTEEN SIDES

The rats were allowed to choose between the triangle and the heptadecagon (fig. 5). From the results of the foregoing experiments we should expect that the heptadecagon would be preferred to the triangle, but no more than the pentagon and the nonagon were preferred to the triangle. The result showed that the mean frequency of the choice of the heptadecagon by thirty rats in the total choices of sixty for each was 34.40 ± 2.33 (table 1), 4.40 above the theoretical mean of thirty. The difference is 0.97 times the sigma of the difference, a barely significant difference.

The rats did not prefer the heptadecagon to the triangle as much as the pentagon or the nonagon, although the first diverging point of the heptadecagon is much closer to the starting box. This result excludes the hypothesis that the first diverging point is the only cue, by which the discrimination is made. As shown in experiment II it has some influence in the choice, but is not the only factor that determines the choice. The drop in preference in this experiment needs some explanation. From the results of the foregoing experiments the rats would have been expected to prefer the heptadecagon to the triangle as frequently as, if not more often than, they chose the pentagon and the nonagon. Why the heptadecagon was not preferred as much as these last two figures may be due to the following reasons: In running through the heptadecagon the rats had to turn sixteen times in quick succession because all but one of the sides of the figure were very much reduced in length. This zig-zag passage annoyed

the rats a great deal; especially when they put on some speed. Often they bumped their noses against the wall at the turning because their effort to clear one turning compelled them to dash forward and carried them on too close to the next turning to make another successful twisting. In the training period it took three times as long to make them go through the heptadecagon as to force them through the triangle. This motor difficulty may have decreased in part the preference for the heptadecagon.

In comparing the two critical ratios, 0.97 in this experiment and 1.41 in experiment II (3- *vs.* 5-side discrimination), there is no significant difference. Hence between the pentagon and the heptadecagon we should expect little or no preference. The next experiment tested this expectation.

Experiment VI: Five versus Seventeen Sides

The rats were made to choose between the pentagon and the heptadecagon (fig. 6). It was found that the mean frequency of the choice of the heptadecagon by thirty rats in the total choices of sixty for each was $32.13 + 2.60$ (table 1), 2.13 above the theoretical mean of 30. The difference is only 0.46 times the sigma of the difference; it is not significant.

Summarizing the results so far: the rat prefers in general a more complicated pattern to a simpler one, but there seems to be a threshold in the complexity of pattern to be preferred. Why this is so is still a mystery. As we go from the triangle to the heptadecagon, the following geometrical relationships hold: the number of sides and angles increase proportionally to the series $(2^n + 1)$; the area decreases proportionally to the series $(\frac{1}{2})^n$; the first diverging point of the more complex figures comes closer to the starting box, proportional to the series $(\frac{1}{2})^n$; the sides of the polygons—except the base, which remains constant—decrease proportionally to the series $(\frac{1}{2})^n$. These relationships are shown in the following table, along with the critical ratios obtained in the discrimination of each of these figures from the triangle.

Geometrical Relationship in the Patterns

Pattern	Triangle	Pentagon	Nomagon	Heptadecagon
Number of sides and angles......	$2+1=3$	$4+1=5$	$8+1=9$	$16+1=17$
Area....................................	A*	$\dfrac{A}{2}$	$\dfrac{A}{4}$	$\dfrac{A}{8}$
Sides—except the base..............	a†	$\dfrac{a}{2}$	$\dfrac{a}{4}$	$\dfrac{a}{8}$
Distance of second turn from start..	a†(1+1)	$a(1+\tfrac{1}{2})$	$a(1+\tfrac{1}{4})$	$a(1+\tfrac{1}{8})$
Critical ratios in comparison with triangle.......................................		1.41	1.64	0.97

$A^* = \dfrac{a^2 \sin 60°}{2} = \dfrac{\sqrt{3}\, a^2}{4}$, where a† = a side of the triangle.

These patterns are related geometrically one to another in a definite order, but the critical ratios show no definite variation. If the discrimination depended mainly upon some simple sensory processes, the critical ratios would be expected to vary more regularly. If they should increase or decrease in an arithmetical series, Weber's law would hold here since the patterns are related one to another in geometrical series.

In the foregoing experiments it is noted that the nonagon was discriminated from the triangle, but not from the pentagon; the heptadecagon was discriminated from the triangle, but not from the pentagon. In short, the rats discriminated the triangle from the other figures, but did not discriminate these three from one another. This analysis indicates that a threshold in discrimination of maze patterns by the rat lies somewhere between the triangle and the pentagon under our experimental conditions, and an increase in mere complexity of physical elements in patterns failed to stimulate the rat proportionally. In order to see what maze patterns other than those which are complex the rat can discriminate from the triangle the following experiment was carried out.

EXPERIMENT VII: THREE VERSUS FIVE No. 2

The pentagon No. 2 was formed by cutting a little notch, ten inches deep, at one vertex (fig. 7). This pentagon differs very slightly from the triangle. Except the little twist at the notch, the path lies parallel to the triangle all the way through. The rats were given the choice between this pentagon No. 2 and the triangle. It was found that the mean frequency of the choice of the pentagon by thirty rats in the total choices of sixty for each was 35.13 ± 2.68 (table 1), 5.13 above the theoretical mean of 30. The difference is 1.09 times the sigma of the difference. In comparing this with the preference shown for the first pentagon, the critical ratio fell from 1.41 to 1.09, but 1.09 is yet a tolerably significant difference.

In this situation the cues in the two paths, triangular and pentagonal, differ the least; and yet the rats were able to discriminate between the two. This result invites a more critical study in the same situation. So far the variability in performance has been controlled statistically, that is, each group discriminating any pair of patterns had a number of cases such that the group means were relatively stable and dependable, although within the groups the individuals differed widely in their choices. And the group means obtained showed certain consistencies as to the power and limitation in discrimination. But in order to explain such consistencies, and to discover the causal factors that enabled the rats to discriminate and prefer, an experimental control of variability in performance is of utmost importance. The next two experiments were made with this point in mind.

EXPERIMENTS VIII AND IX: THREE VERSUS FIVE No. 2, WITH A SELF CONTROLLED GROUP

In experiment I, thirty rats were given choice between two practically identical triangles, and as was expected, they failed to discriminate between the two. The individual records show,

however, that some rats chose the path on the right consistently, while others chose the path on the left consistently, and only six chose one path as often as the other; so that in sixty choices they scored nearly thirty on each path. There were, however, as many that chose the right as the left, thus making the group mean close to the theoretical mean of thirty. In experiment VIII the original group of thirty rats was expanded to 157. These rats chose between the two triangular paths just as in experiment I (fig. 1). The mean frequency of the choice of the right-hand path by this large group was 33.05, which is within the standard error of the theoretical mean of thirty (table 1). As far as the numerical values of the means, reliability coefficients, and intercorrelations are concerned, there is a very little difference between the first group of thirty and the expanded group of 157. This shows that what is true for thirty holds equally well for 157, and proves that the original group of thirty was a random sampling as far as the discrimination in patterns is conceived.

In experiment IX (*a*) the individual records of the 157 rats were examined, and the rats whose gross scores fell within the standard error of the theoretical mean of thirty (i.e., from 26 to 34) were selected, and their scores were retabulated. There were thirty of these. It was found that the mean frequency of the choice of the right-hand path by these thirty in the total choices of sixty for each was 30.27 ± 0.49 (table 1). The reliability coefficient by the half-*vs.*-half method was —.88; the same by the odd-*vs.*-even method, —.63. Within the first and last halves the coefficients were .50 and .53 respectively by the odd-*vs.*-even method. These results show that those scoring high in the first half scored low in the last half, or the low scorers in the first half scored high in the last half. Between the scores on the odd days and on the even days, the same reverse relation holds. But within each half the scores on the odd days are correlated positively with the scores on the even days. The coefficients are, however, in the neighborhood of .50. These correlations considered together indicate relatively unstable performance through-

out. The intercorrelations show a similar instability. The diagonals are not correlated; the initial days tend to be negatively correlated with the final days. These low correlations are expected, since the rats were selected on the basis of chance scores.

In experiment IX (*b*) these thirty selected rats were made to choose between the triangle and the pentagon No. 2 (fig. 7). They were given training in each path as usual before the choice series. The result showed that the mean frequency of the choice of the pentagon No. 2 by these thirty in the total choices of sixty for each was 36.50 ± 2.44 (table 1). The reliability coefficient by the half *vs.* half method was .92; the same by the odd-*vs.*-even method, .97. Within the first and last halves the coefficients were .91 and .95 respectively. The high reliability is further attested by the high intercorrelations. In contrast to what they did in the preceding experiment the rats showed a very highly stable behavior in this experiment. The correlation between the two series of individual scores was as low as .16.

Comparing the two means in (*a*) and (*b*) we find that, when the right hand path was the triangle (i.e., the same as the alternate left path), the rats chose this 30.27 times out of 60, but when it was changed to the pentagon, they chose this 36.50 times out of 60. The difference between these two means is highly significant, the critical ratio being as high as 4.10. This high discrimination and preference shown by the self controlled group strongly supports the former conclusion that the rat can discriminate maze patterns, and indicates that the evidence presented to support this conclusion was *not* due to the accidental selection of the particular group.

SUMMARY AND CONCLUSION

1. The rat discriminated the pentagon from the triangle and preferred the pentagon.

2. The rat discriminated the nonagon from the triangle and preferred the nonagon, but the preference shown for the nonagon

was not any greater than the preference shown for the pentagor The rat failed to discriminate between the pentagon and nonagor

3. The rat discriminated the heptadecagon from the triangl and preferred the heptadecagon, but the preference shown fo heptadecagon was not any greater than the preference shown fo the pentagon. The rat failed to discriminate between the pen tagon and the heptadecagon.

4. A threshold in discrimination of maze patterns used in th present experiment seems to lie between the triangle and th pentagon. The patterns more complex than the pentagon coul not be discriminated from one another.

5. The rat discriminated the triangle from the pentagon No. 2 which was formed by cutting a little notch at one vertex of th triangle.

6. The possibility of the choice of the paths by a mer position-habit was excluded by: (*a*) a group of thirty rats an also another of 157 which failed to show preference for the righ or left path when both were identical in pattern; and (*b*) the ra chose the nonagon when it was lying on the right side of th triangle, but did not choose it when it was on the right side o the pentagon. The heptadecagon on the right side of the triangl was chosen, but the same pattern on the right side of the pentagor was not chosen.

7. It is concluded that the rat prefers in general a more com plex pattern to a simple one within the limits of discriminability.

---

[4] The answer to the question why the rat showed the preference foun in these experiments is not ready. Two possibilities, however, are con sidered at present. (1) Orientation; the complex patterns seem to orien the rat more directly back to the food box; that is, the complex path are seemingly the easiest and the most direct route to food. (2) Differentia cues; the complex patterns that require more difficult motor adjustmen in order to go through them, may give the rat more cues to remembe the paths by. A further experiment bearing upon these points is unde way.

TABLE 1

THE MEAN FREQUENCIES OF THE CHOICE OF THE PATTERNED PATTERNS

n=30, except in Experiment VIII where n=15r   The theoretical mean =30±3.87 / = nvq?

Experiment	Patterns offered for choice	Mean of the choice of the second pattern	σM	σ	† σσ	Difference between the actual and theoretical means	‡ Sigma difference	Critical ratio
I	3 vs. 3	29.13	2.57	14.11	1.82	0.87	4.65	0.19
II	3 vs. 5	36.37	2.33	12.77	1.65	6.37	4.52	1.41
III	3 vs. 9	37.67	2.60	14.30	1.85	7.67	4.66	1.64
IV	5 vs. 9	30.33	2.89	15.82	2.04	0.33	4.53	0.68
V	3 vs. 17	34.40	2.33	12.78	1.65	4.40	4.52	0.97
VI	5 vs. 17	32.13	2.60	14.24	1.84	2.13	4.66	0.46
VII	3 vs. 5 No. 2	35.13	2.66	14.66	1.89	5.13	4.71	1.09
VIII	3 vs. 3	33.05	1.14	14.34	0.81	3.05	4.03	0.76
IX-A	3 vs. 3	30.27	0.49	2.67	0.34			
IX-B	3 vs. 5 No. 2	36.50	2.44	13.35	1.73	IX(B)−IX(A) 6.23	2.32§	4.10

$* \; \sigma_M = \dfrac{\sigma}{\sqrt{n}}$ $\dagger \; \sigma\sigma = \dfrac{\sigma}{\sqrt{2n}}$ $\ddagger \; \sigma \text{ diff.} = \sqrt{\sigma I^2 + \sigma II^2}$ $\S \; \sigma \text{ diff.} = \sqrt{\sigma I^2 + \sigma II^2 - 2r\sigma I \, \sigma II}$, where $r=.16$.

TABLE 2

RELIABILITY COEFFICIENTS

n=30   n=157 in Experiment VIII

Experiment	Half vs. half		Odd vs. even, whole		Odd vs. even, first half		Odd vs. even, last half	
	$r_{(1,2,3,4,5)(6,7,8,9,10)}$	Corrected by Brown's formula*	$r_{(1,3,5,7,9)(2,4,6,8,10)}$	Corrected by Brown's formula	$r_{(1,2,3)(2,4)}$	Corrected by Brown's formula	$r_{(7,9)(6,8,10)}$	Corrected by Brown's formula
I	.63	.77	.90	.95	.83	.89	.87	.93
II	.73	.84	.71	.83	.81	.90	.71	.83
III	.64	.78	.74	.85	.90	.95	.88	.94
IV	.70	.92	.92	.96	.87	.93	.92	.96
V	.77	.87	.89	.94	.74	.85	.85	.92
VI	.74	.75	.91	.95	.88	.94	.77	.87
VII	.61	.92	.91	.95	.72	.84	.85	.92
VIII	.68	—	.80	.73	.73	.86	.80	.89
IX A	.76	.92	.46	.63	.33	.50	.37	.53
IX B	—	—	.74	—	.74	.91	.90	.95

* Brown's formula $r = \dfrac{2r}{1+r}$

TABLE 3

INTERCORRELATIONS

n = 30

Experiment I

Days	2	3	4	5	6	7	8
1	.72	.45	.44	.58	.57	.32	.49
2		.58	.46	.34	.47	.49	.71
3			.47	.41	.41	.41	.47
4				.58	.47	.52	.46
5					.72	.63	.62
6						.47	.46
7							.49

Experiment II

Days	2	3	4	5	6	7	8	9	10
1	.40	.57	.50	.36	.41	.34	.37	.36	.38
2		.49	.30	.40	.05	.31	.17	.27	.30
3			.57	.65	.69	.59	.62	.55	.54
4				.64	.68	.61	.59	.37	.44
5					.43	.58	.58	.30	.42
6						.53	.70	.46	.38
7							.45	.46	.36
8								.49	.30
9									.56

Experiment III

Days	2	3	4	5	6	7	8
1	.33	.37	.44	.47	.53	.31	.68
2		.72	.55	.50	.71	.58	.72
3			.63	.49	.47	.44	.49
4				.71	.54	.44	.43
5					.58	.38	.43
6						.62	.70
7							.57

Experiment IV

Days	2	3	4	5	6	7	8	9	10
1	.26	.31	.55	-.10	.06	-.13	-.02	.13	.10
2		.70	.63	.43	.47	.32	.43	.42	.39
3			.56	.65	.70	.69	.78	.73	.71
4				.79	.79	.76	.66	.66	.72
5					.72	.76	.62	.69	.63
6						.76	.60	.63	.71
7							.72	.67	.76
8								.62	.89
9									.87

TABLE 3—(*Continued*)

n=80

Experiment V

Days	2	3	4	5	6	7	8	9	10
1	.36	.48	.39	.44	.44	.45	.39	.17	.16
2		.21	.17	.18	.05	.18	.19	.13	.39
3			.54	.38	.42	.38	.40	.42	.07
4				.55	.60	.65	.64	.66	.46
5					.53	.61	.68	.58	.52
6						.65	.53	.62	.44
7							.73	.69	.63
8								.70	.61
9									.50

Experiment VII

Days	2	3	4	5	6	7	8	9	10
1	.37	.47	.23	.19	.16	.02	−.22	−.15	.05
2		.75	.52	.57	.43	.55	.36	.40	.18
3			.94	.81	.67	.65	.35	.31	.14
4				.63	.72	.57	.38	.47	.17
5					.76	.83	.70	.71	.51
6						.79	.65	.57	.59
7							.76	.90	.66
8								.75	.71
9									.81

n=167 in Experiment VIII

Experiment VI

Days	2	3	4	5	6	7	8	9	10
1	.59	.48	.41	.46	.54	.62	.49	.42	.11
2		.79	.50	.61	.66	.54	.57	.71	.24
3			.65	.58	.58	.50	.39	.83	.25
4				.73	.63	.71	.53	.61	.54
5					.66	.56	.40	.77	.36
6						.70	.56	.69	.45
7							.72	.58	.43
8								.75	.49
9									.62

Experiment VIII

Days	2	3	4	5	6	7	8	9	10
1	.61	.52	.46	.50	.40	.36	.35	.39	.32
2		.48	.52	.49	.42	.33	.37	.40	.24
3			.68	.54	.46	.46	.41	.45	.36
4				.67	.55	.52	.45	.29	.41
5					.66	.64	.55	.54	.51
6						.65	.57	.59	.58
7							.69	.86	.65
8								.73	.72
9									.71

TABLE 3—(Concluded)

n=30

Experiment IX(A)

Days	2	3	4	5	6	7	8	9	10
1	.20	.20	.14	.07	.07	−.29	−.21	−.30	−.06
2		.15	.25	−.39	−.02	−.47	−.11	−.48	−.25
3			.45	0	−.33	−.41	−.66	−.19	−.70
4				.26	−.09	−.20	−.63	−.45	−.72
5					.03	−.02	−.20	−.22	−.30
6						−.08	.53	−.21	−.01
7							.39	.21	.26
8								0	.42
9									.36

Experiment IX(B)

Days	2	3	4	5	6	7	8	9	10
1	.63	.74	.66	.52	.50	.64	.49	.48	.29
2		.57	.45	.56	.41	.71	.51	.52	.70
3			.63	.72	.60	.64	.65	.59	.57
4				.31	.62	.69	.50	.44	.48
5					.65	.72	.64	.83	.76
6						.73	.68	.76	.63
7							.78	.60	.55
8								.59	.46
9									.66

WEBER'S LAW IN THE DISCRIMINATION OF MAZE DISTANCE BY THE WHITE RAT

BY

JOSEPH G. YOSHIOKA

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—George M. Stratton, Warner Brown, and Edward C. Tolman, Editors.

Price per volume, $3.50.

WEBER'S LAW IN THE DISCRIMINATION
OF MAZE DISTANCE BY THE
WHITE RAT*

BY

JOSEPH G. YOSHIOKA

CONTENTS

STATEMENT OF PROBLEM

The present research is an attempt to verify Weber's Law in the discrimination of maze distance by the white rat, and tries to answer the following question: Does the relative degree of discrimination of maze distance by the white rat remain constant with changes of absolute length of path? Or, more specifically: Given a long path L and a short path S, whose difference in length is d,[1] does the number of the choices of the short path remain the same when both the long and short paths are doubled in length with a consequent doubling of their difference?

[1] L, S, d. After doubling, $2L$, $2S$, $2d$.

HISTORICAL

Animal psychophysics has little or no history, but a brief survey of the literature that led, directly or indirectly, to the inception of the present problem will be timely.

Yerkes (1907) tried to verify Weber's Law in vision in a dancing mouse. Only one dancer was used. The apparatus was the Yerkes discrimination box, whose alleys were lighted differentially by reflected light. The rat was taught to choose the alley lighted by the variable light. The choice of the alley lighted by the standard light brought with it an electric shock. The criterion of learning was 75 per cent or more of correct choices. Fifty or one hundred trials were given in a single sitting. Yerkes showed that under these experimental conditions the dancer was able to discriminate difference of light intensities of 10 per cent, or, more specifically, the differences between 80 and 72 hefners, 20 and 18 hefners, and 5 and 4.5 hefners. Yerkes concluded that Weber's Law probably holds. With only one subject and with some inconsistencies in the results, a stronger assertion could not justifiably be made.

Watson (1907) found that the rat depends mainly upon kinaesthetic sensations in maze-learning. The deprivation of olfactory, tactual, visual, and auditory senses did not appreciably decrease the rat's learning ability for a Hampton Court maze. Although Vincent (1915a, 1915b, 1915c), Carr (1917a, 1917b, 1917c), and Richardson (1921) later proved that the rat could use other sensory cues to advantage in a maze solution, Watson's conclusion could by no means be entirely overthrown. If kinaesthesis is the main sense upon which the rat depends in finding its way in a maze, then distance would be an important factor.

De Camp (1920) devised a maze with no blind, in order to find out the rôle that distance plays in maze solution. Maze A was rectangular in shape, maze B circular. Both consisted of a circuit alley, like a race track. A movable food box could be placed at any point on the circuit alley, so that its distance from

the fixed starting box might be varied at will. This arrangement is such that, except when the food box is at the diametrically opposite point to the starting box, the circuit route in one direction is shorter than the similar route in the other direction. Further, the nearer the food box is to the starting box, the greater is the ratio of the short path to the long path. The same ratios were tried in both directions, right and left, in order to control the space error. Eight rats were used. De Camp concluded that the differential limen, DL (the difference between the lengths of the long and short paths divided by the length of the long path) is .10.

The criterion of learning adopted by De Camp was that the rat was "clearly taking (preferring) the shorter path." This criterion lacked the objectivity really needed for the determination of a DL. But, taking his tables at their face value, they show that one rat had a DL of .10 in maze A, where the long path was 245 inches, and two other rats had the same DL in maze B where the long path was 217 inches. A constancy of the DL with the change of absolute length was here indicated, which is the essence of Weber's Law. Unfortunately his determinations were not reliable, and moreover, his own discussion did not extend to this latter phase of the problem.

Kuo (1922), with a four compartment maze, showed that distance was effective only after other factors had been eliminated. The first compartment led into a true path, which was the shortest route to food. The second compartment led to food by a roundabout way. The third confined the rat for twenty seconds. The fourth gave an electric shock. It was found that the fourth compartment was eliminated first; the third, next; the second, last. Only after the electric shock compartment and the confinement compartment had been eliminated did the distance factor demonstrate itself. This finding suggests that two paths should be made as nearly alike as possible except in length, if a clear cut result in distance discrimination is desired.

No other work has been found which has a direct bearing on the present problem.

METHOD AND APPARATUS

Method—

The method used is that of right and wrong cases. The choice of this method was based upon the following reasons.

(1) The simplified form of this classical method can be approximated in animals without violent deviation from the procedure prescribed by Jastrow.

(2) Weber's Law can be verified without determining the DL.

(3) The practice (the number of runs) can be made constant and conveniently short so that the mathematical treatment of data is simplified and, moreover, reliable.

Apparatus—

Two mazes, maze I and maze II, were used. The plan of maze I is shown in figure 1. It is essentially a two-alley discrimination box in the shape of a toadstool. The straight portion is made of dressed redwood, three-quarter inches by seven and one-half inches; the semicircular portion is made of galvanized sheet iron, seven and one-quarter inches wide. At the base of the maze is the food box, F. The food pan, $f.p.$, is placed near the baseboard, equidistant from the two sides. The food box has three doorways: E, entrance at the center; D_R, exit on the right side; D_L, exit on the left. Each doorway is four inches wide, having a galvanized sheet iron door seven and one-quarter inches by four inches, which fits in grooves in the side posts, one inch by one inch by fifteen inches, nailed on each side of the doorway. The door can be pulled up and down quietly by a cord. The entrance E leads into the inner alley I, which begins as a wide alley, but soon is divided into two alleys. In the middle semicircle in the expanded portion, a number of doorways are cut, three inches wide, and three inches high from the bottom. Door C is located at the point directly opposite to

the entrance *E*. At a point six and one-half inches distant from the center of door *C*, on the right side, door R_5 is cut; at the corresponding point on the left side door L_5 is cut. Similarly R_4 and L_4, R_3 and L_3, R_2 and L_2, R_1 and L_1, each pair six and
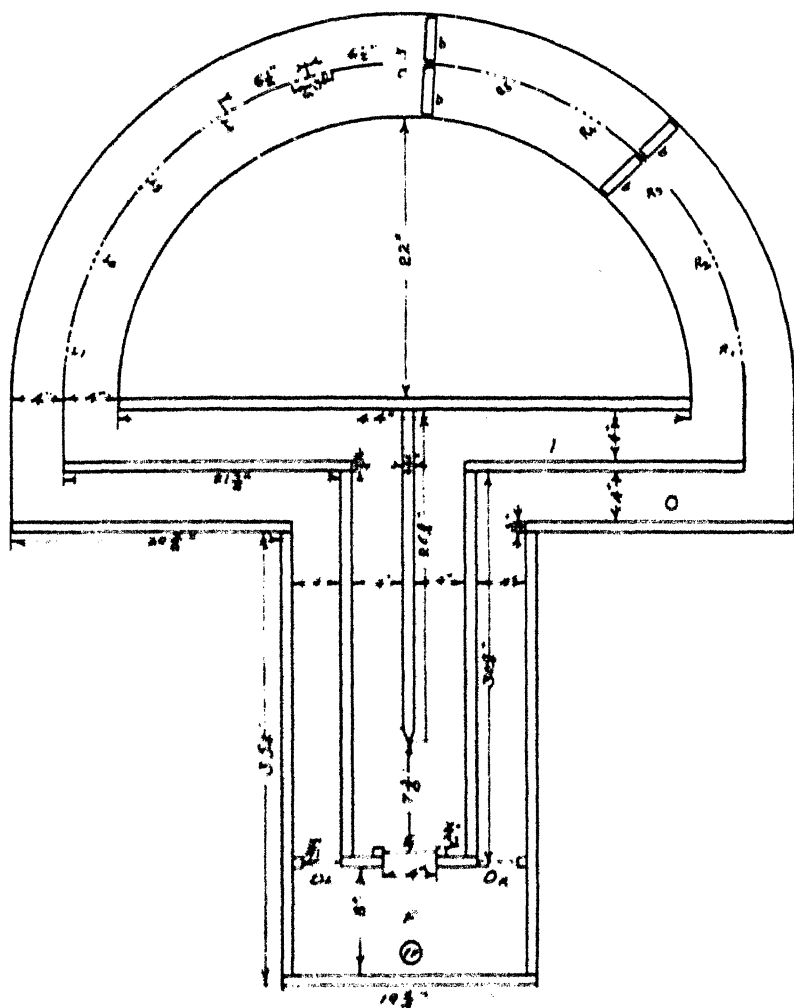
Figure 1. Maze 1.

E, pulley door at entrance; *I*, inner alley; *O*, outer alley; *C*, central door (always open); R_1, R_2, R_3, R_4, R_5, L_1, L_2, L_3, L_4, L_5, adjustable doors (*R*, open); *b*, block; *Dn*, Dn_1, pulley doors; *F*, food box; *fp*, food pan.

one-half inches farther along, respectively. Each doorway can be completely covered up by a piece of metal, three and one-half inches by seven and one-quarter inches, which is held tightly in place by a metal clip. Door *C* is always open, while only one of the other doors is open in any experimental situation. An open door is the only channel of communication from the inner to outer alley, and is flanked on the farther end by a pair of wooden blocks *b*, which prevent farther passage both in the inner and outer alleys. Hence the blocks, wherever they happen to be, mark the end of both double alleys, and compel the rat to go back through the outer alley parallel to the inner alley that it has chosen at the start. In other words, a circuit is restricted to one side, either right or left; the right circuit is completed through the right inner and outer alleys; the left circuit is completed through the left inner and outer alleys. Figure 1 shows one pair of blocks on the right-hand end of the open door *C*. The left double alleys, consequently, are the long path: it is approximately 211 inches long from the entrance *E* to the food pan, *f.p.* The right path shown in the figure is a short circuit through R_3, and is 172 inches long. If L_3, which is the same distance as R_3 from the entrance *E*, is open, and blocked on the right, and *C* is blocked on the left, then the right path is now the long path, 211 inches long; the left path is the short path, 172 inches long. Five pairs of short paths can be formed to compare with the constant long path, making five experimental situations:

Situation I.   (*a*) Choice between the long path on the left and the short path through R_1; (*b*) choice between the long path on the right and the short path through L_1.

Situation II.   (*a*) Choice between the long path on the left and the short path through R_2; (*b*) choice between the long path on the right and the short path through L_2.

Situation III.   (*a*) Choice between the long path on the left and the short path through R_3 (illustrated in fig. 1); (*b*) choice between the long path on the right and the short path through L_3.

Situation IV. (*a*) Choice between the long path and the short path through R_4; (*b*) choice between the long path and the short path through L_4.

Situation V. (*a*) Choice between the long path and the short path through R_5; (*b*) choice between the long path and the short path through L_5.

Maze II is exactly like maze I except that it is twice as large. The description given for maze I applies to maze II, save that every dimension is doubled, except the dimensions of the following, which remain the same: the food box; width of the alleys; three doorways, E, D_R, and D_L, leading out from the food box; and the size of the doorways cut in the middle semicircle. The constant long path is 422 inches long; the pairs of short paths are doubled in length, and shortened by steps of 26 inches. The length of the paths in the different situations are given in the following table:

TABLE I

LENGTH OF PATHS IN DIFFERENT SITUATIONS

Roman numerals refer to situations; *L* long path; *S* short path; *d* difference between the long and short paths; *R* ratio of the short path to the long path.

Situation	Maze I				Maze II			
	L	*S*	*d*	*R*	*L*	*S*	*d*	*R*
I	211"	146"	65"	1.44	422"	292"	130"	1.44
II	211"	159"	52"	1.33	422"	318"	104"	1.33
III	211"	172"	39"	1.23	422"	344"	78"	1.23
IV	211"	185"	26"	1.14	422"	370"	52"	1.14
V	211"	198"	13"	1.07	422"	396"	26"	1.07

Procedure

1. CONTROL OF VARIABLE ELEMENTS

LIGHT. The experiment was conducted in a dark room. A frosted 110 watt tungsten lamp was suspended from the ceiling, five feet above the center of the inner semicircle of the maze, so that the inner and outer alleys were equally illuminated throughout. The straight inner and outer alleys were approxi

mately equally illuminated since they were symmetrically placed with reference to the light. In maze II, two lamps were used.

The two paths thus illuminated look exactly alike from the entrance. The wooden blocks which mark the ends of each alley are not visible until the rat is quite near them. Also any open door through which the rat passes from the inner to the outer alley comes into view only when the rat actually comes up to it, and its appearance, when visible, is like that of any other, due to the fact that the extent of the sector of the circular path from which it is visible is the same whatever the position of the particular door.

SMELL. The food used in the maze was sunflower seeds and dry bread soaked in water. Whatever smell diffused, did so evenly in the right and left paths, because these were placed symmetrically with respect to the food pan. The doorways in the middle semicircle are also radially symmetrical with respect to the food pan. The absolute distances of these doors from the food pan do not vary more than 6 per cent of the longest distance (a straight line connecting the food pan with door C. Hence the diffusion coefficients at these doors must be practically constant. And, moreover, after each set of the experiment, the floor of the pathways was thoroughly cleansed.

KINAESTHETIC PATTERN OF THE PATHWAYS. The long path and the short path differ only in length and in the reversal of the turns.

THE RATS. The rats used in the experiment were from the stock white rats in the Psychological Laboratory, University of California. The experimenter bred and reared them. After the weaning period, they were fed on McCollum's standard diet No. 1, with an occasional allowance of fresh lettuce. The food was made into soft dough and given once a day; 10 per cent of body weight was the daily ration for each rat. All the animals began and finished the experiment in good health. Their ages varied from five and a half to six months, which is within the period of maximum activity as attested by Slonaker (1912) and

Richter (1922). The total number of rats used was 197. Both sexes were used, evenly distributed as far as practicable in the different situations.

2. ROUTINE OF THE EXPERIMENT

DISTRIBUTION OF THE SUBJECTS. Each rat was given a choice of the long path and one short path. For example, rat 1 was to choose between the long path and the short path through door R_1; rat 2 was to choose between the long path and another short path, through door L_3, and so on. Five rats, composed of three males and two females, or three females and two males, formed a group which learned all of the variable doors on one side, one rat to a door. A second group learned all the corresponding doors on the other side. Two such groups were run at a single sitting. No variable door was open twice in succession. The order of presentation of the variable doors was changed irregularly. The following gives some of the orders practiced:

$$R_1 \ R_2 \ R_3 \ R_4 \ R_5 \ L_5 \ L_4 \ L_3 \ L_2 \ L_1$$
$$R_2 \ R_4 \ R_5 \ R_3 \ R_1 \ L_3 \ L_5 \ L_2 \ L_4 \ L_1$$
$$L_1 \ R_1 \ L_3 \ R_2 \ L_5 \ R_3 \ L_4 \ R_4 \ L_2 \ R_5$$
$$R_3 \ L_5 \ R_1 \ L_4 \ R_5 \ L_3 \ R_2 \ L_2 \ R_4 \ L_1$$
$$L_4 \ L_3 \ R_1 \ R_2 \ L_5 \ L_4 \ R_3 \ R_4 \ L_2 \ R_5$$

The possibilities of such permutations are almost unlimited. This irregularity cancelled the tendency to track preceding rats. One rat might be preceded by another rat of the same or of the opposite sex.

In all, each of the ten variable doors in maze I and each of the ten variable doors in maze II was learned by a set of ten rats, except R_3, L_4, R_4 in maze I, which were each learned by nine rats only. Ninety-seven rats completed maze I; 100 rats completed maze II.

TIME OF EXPERIMENT. The experiment began in September, 1924, and ended in May, 1925. Maze I was used first, and discontinued in January, 1925. Maze II was used for the remaining period. The daily experiment was done between 8 a.m. and

5 p.m.   Any given group of five rats was run at approximately the same time each day.

DAILY PROGRAM.   Six trials per day for nine days was the program for each rat.   Before a rat was placed in the maze for the first time it had gone for two days on half-rations fed to it in the food box.   When the experiment had actually begun, the rat was allowed only a nibble of food after each run.   After a group had finished the day's program of six runs each, they were fed the rest of their food in their own cages.   The running was recorded graphically.   Each maze had section numbers along the alleys, and a tracing could be drawn by the experimenter with reference to these section numbers.   While the distance calculated on the basis of these tracings was not exact, it was a fair approximation.   The time was taken by a $\frac{1}{5}$ second stop watch, but the speed of the rats was so great, particularly at the later stages of learning (about 42 inches per second) that these time records were not very reliable.

EMOTIONAL FACTORS.   The rats were thoroughly accustomed to being handled.   Yet the first introduction to the maze so upset some of them that no amount of care or of threats availed to keep them moving.   These scared animals simply crouched down somewhere along the alley, usually at a corner, and '' went to sleep.''   To economize time, at the end of three minutes in maze I, and of six minutes in maze II (assuming that twice the distance requires twice as much time to traverse), these passive animals were taken out and started anew from the entrance. Other animals were so restlessly active that they retraced the inner alleys without getting any nearer to the solution.   To these rats the same time limit was applied.   If any rat scored four or more of these incomplete runs, it was discarded.

TIME ERROR.   In the beginning, the rats were learning what to do in the maze; they were apt to loiter along the way inspecting every bit with curiosity, running, stopping, and retracing. The time sequence under these conditions was relatively inconstant and the time error relatively large.   But in the later stages of learning, this erratic running was mostly eliminated.   The

rats made a straightforward round trip through either the long or short path, as the choice happened to be. Hence each such trip was made within narrow limits of time (five seconds per trip). The time error under these latter conditions was relatively small and constant, and may safely be assumed to have been unimportant for a comparison of the discrimination scores.

It must be noted, however, that the experimental program was such that the standard stimulus and the variable stimulus were not encountered an equal number of times. Hence, the comparison judgments were made between a stimulus immediately present and another stimulus recalled sometimes from a relatively recent and sometimes from a relatively remote past. This introduces another type of error. But, methodologically, it is almost impossible to eliminate this latter type of error so long as the judgment of an animal has to be expressed in terms of gross motor performance. Further, the effect of this error was, perhaps, partly eliminated by our arbitrary criterion of learning, which was that, in the first four days the path other than the one later predominantly chosen, must have been taken at least six times. And hence on the fifth day, every rat that finished the experiment had had the same minimum experience of the alternate path.[2] Again, the evil was probably not so great as might be inferred, because we were concerned in comparing the scores in the two mazes, and, whatever the error, it can be assumed to have been relatively the same for both mazes.

Finally the free-learning method chosen had the advantage of offering an opportunity to study just how the rat learned the maze under "natural" conditions.

SPACE ERROR. The right and left space errors were eliminated by combining the scores made on the right side with the similar scores made on the left.

---

[2] In my later study of the discrimination of maze patterns, the rats were forced through each of the two alternate paths just before a daily free choice was given. This "Daily-Practice" method was found to bring out better discriminative preferences than the free-learning method. "A Preliminary Study in Discrimination of Maze Patterns by the Rat," *Univ. Calif. Publ. Psychol.* (1928), 4:1–18.

A disturbing space feature was position habits. Some rats tended to take the right side only, irrespective of its length, and some the left. This difficulty was partly eliminated by the criterion cited above, that, in the first four days the path other than the one later predominantly chosen must have been taken at least six times.

THE CRITERION OF SCORES. The constant method is concerned exclusively with the frequency of true comparison judgments. Hence our scores should be the frequency of true choices of the short path. The animals had however first to dispel fear of the new situation in the maze, to overcome curiosity, and to habituate themselves to the maze in general before any such true discriminations were possible. This necessity is not a novelty; even in human psychophysical problems a certain amount of training is imperative. But in our present case the difficulty is to decide how to separate scores scattered in a nine-day period into learning scores, on the one hand, and discrimination scores, on the other. Actually the scores of the last five days were chosen as discrimination scores. The justification for the decision will be discussed in full, with empirical evidence, under "Results."

TYPES OF SCORES. Besides the choice of the short path and the choice of the long path by a straightforward running, designated score P and score P_e, respectively, we observed erratic retracing in the same alleys. Further observation distinguished three types of such retracing: (A) confused running; (B) misjudged running; (C) disturbed running.

(A) "Confused running" includes more than one retracing in both the short and the long paths. It is a typical trial-and-error running and tends to occur in the early stage of learning. (B) "Misjudged running" includes just one retracing in the path not finally chosen. The rat starts along a path, swings around with no hesitation, retraces the path, and takes the alternate path. This type of retracing is found in all stages of learning. (C) "Disturbed running" includes one or more retracings in the path finally chosen. This seems due to incom-

plete learning. The rat starts along a path whose characteristics are only vaguely known. As it advances, some extraneous disturbance, such as a sudden noise or inrush of air upsets it, making it retrace. As learning progresses, the rat becomes less and less distracted by such disturbances, and this type of retracing tends to disappear.

Type A   Type B   Type C
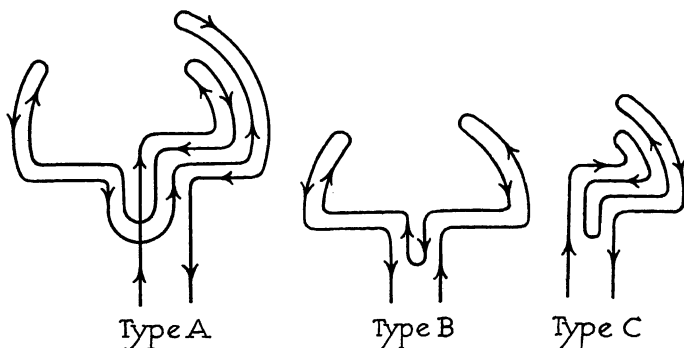
The three types of retracing are designated as scores A, B, and C, when the final choice is the short path; as scores A_c, B_c, and C_e, when the final choice is the long path.

The following types of scores were also computed:

Score S = the sum of the scores A, B, and C.

Score S_e = the sum of the scores A_c, B_e, and C_e.

RESULTS

The results are shown in tables 2–6 and in charts I–V. The discussion will be confined to indicating the more significant features in these.

Learning vs. Discrimination—

In order to sort out learning from discrimination in the obtained scores, the data will be discussed under three headings: (1) Daily Averages; (2) Intercorrelation; (3) Condensed Intercorrelations.

1. THE DAILY AVERAGES OF DIFFERENT SCORES

An empirical criterion for the completion of learning can best be found by an examination of the learning curves. When a learning curve reaches a limit and flattens out, it is evident that learning is then more or less complete. In order to see where a flattening of the learning curve occurred, the daily averages of different scores, under the five different situations, were plotted in chart I, figures 1–10. It will be observed that for both mazes I and II, figures 1 and 6, the five P curves (one for each situation) begin more or less together and cut across one another. From the fifth day on, however, they become separated, and keep their respective levels in more or less flat contour. The P_e curves show a similar trend, though in a lesser degree. Here is a graphic indication that on the fifth day the curves assumed a relatively horizontal character and that learning had largely ceased.

Figures 5 and 10 support the same conclusion. The characteristics of the S and S_e curves are the early rise and later dropping to the same more or less flat level. On the fifth day the five pairs of retracing curves flatten out and remain so. It would appear that the scores (both P and S) may, on the fifth day and thereafter, be regarded as primarily discrimination scores, while on the first four days they are mainly learning scores.

A few words on the separate types of retracing. The curves for the A and the A_e scores show the same trend as do the S and S_e curves, i.e., early rise and final drop. They conform to the "typical" error curve. The B and B_e curves tend, on the other hand, to remain more or less flat throughout learning. The B curves maintain a rather high level in situations I, II, and III; and the corresponding B_e curves run along relatively low. But in situations IV and V, the B and the B_e curves tend to levels about equally low. This indicates a relation between the frequencies of P and of B, and the existence of this relation supports us in defining B as a misjudged running. A wrong direction was taken, but the mistake was soon corrected. The C and C_e curves

remain steadily at low levels throughout the learning. The experimenter observed that these scores were made when an extraneous disturbance appeared; and that these scores are due to such disturbances, is evidenced by the shape of the curves.
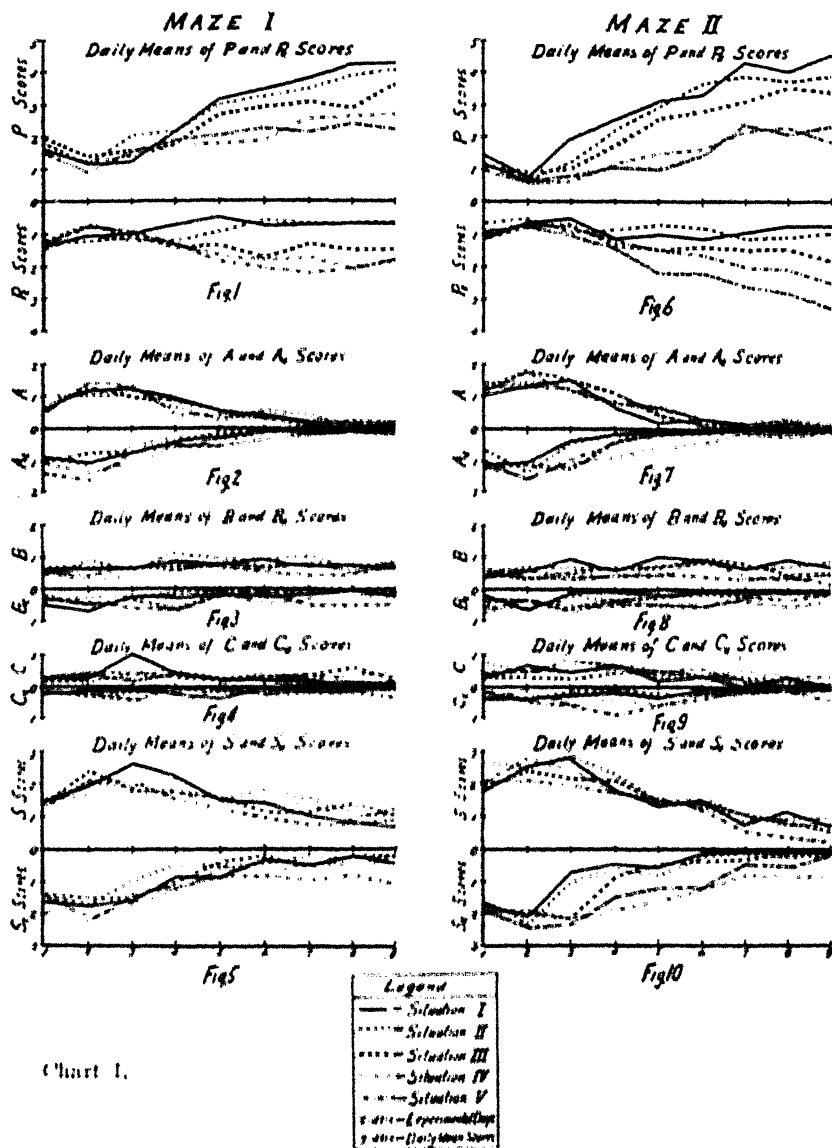
Chart I.

Another indication of these relations between the P and the P_c scores, on the one hand, and the error scores, on the other, is shown by the following percentages:

In the first four days:

Maze I: P, 26%; P_e, 19%; P and P_e, 45%
Maze II: P, 20%; P_e, 15%; P and P_e, 35%

In the last five days:

Maze I: P, 49%; P_e, 22%; P and P_e, 72%
Maze II: P, 48%; P_e, 27%; P and P_e, 74%

In the first four days:

Maze I: S, 31%; S_e, 24%; S and S_e, 55%
Maze II: S, 37%; S_e, 28%; S and S_e, 65%

In the last five days:

Maze I: S, 19%; S_e, 9%; S and S_e, 28%
Maze II: S, 17%; S_e, 9%; S and S_e, 26%

From these figures it appears that in the last five days the choice scores were made approximately three times as frequently as the retracing scores.

As to the three types of retracing, the following percentages were found:

In the first four days:

Maze I: A, 16%; A_e, 15%; A and A_e, 30%
Maze II: A, 20%; A_e, 16%; A and A_e, 36%

In the last five days:

Maze I: A, 4%; A_e, 3%; A and A_e, 7%
Maze II: A, 3%; A_e, 2%; A and A_e, 5%

In the first four days:

Maze I: B, 10%; B_e, 6%; B and B_e, 16%
Maze II: B, 8%; B_e, 7%; B and B_e, 15%

In the last five days:

Maze I: B, 12%; B_e, 4%; B and B_e, 15%
Maze II: B, 10%; B_e, 4%; B and B_e, 14%

In the first four days:

Maze I: C, 5%; C_e, 4%; C and C_e, 9%
Maze II: C, 8%; C_e, 6%; C and C_e, 14%

In the last five days:

Maze I: C, 4%; C_e, 2%; C and C_e, 6%
Maze II: C, 4%; C_e, 3%; C and C_e, 7%

A and *A*, occurred frequently in the beginning, but in the last five days were mostly eliminated. *B* and *B*, had relatively high percentages throughout the learning period, but *B* is much higher than *B*. *C* and *C*, had steady but low percentages throughout the learning period.

In order to show graphically the effects of the differential stimuli, the data were regrouped under each situation and plotted in chart II, figures 11-20. A comparison of these figures shows that the retracing scores distributed themselves more or less symmetrically with respect to the base line, except *B* and *B*, whose peculiar behavior has already been noted. This means that retracing of the *A* and *C* varieties was committed more or less equally in short and long paths. The discrimination scores, *P* and *P*, behave differently. In situation I, where the ratio of the short path to the long path is the greatest, *P* increases enormously in the later stage of learning; *P*, decreases slightly, but increases relatively to the retracing scores. In situation II, the increase of *P* is a little less. In situation III, the increase of *P* is still less. In situation IV, the increase of *P* is very slight and *P*, now begins to increase by a considerable amount. And, finally, in situation V, *P* increases the least; so that *P* and *P*, assume symmetrical positions with respect to the base line in the manner of retracing scores. In situation IV, probably, and in situation V certainly, the choice of the short path was due to chance rather than true discrimination; the long path was chosen as often as the short path. These graphs, taken as a whole, prove that the frequency of the choice of the short path is a function of the difference between the short and long paths; the more difference there is between the short and long paths, the more frequently the short path is chosen.

2. INTERCORRELATIONS

The learning curves, as we have just seen, approached a limit on the fifth day. The standard variations of the means, however (computed but not here presented), are large. Therefore an attempt will now be made by another method to detect

MAZE I
Daily Means of All the Scores in Situation I
Fig.11

Daily Means of All the Scores in Situation II
Fig.12

Daily Means of All the Scores in Situation III
Fig.13

Daily Means of All the Scores in Situation IV
Fig.14

Daily Means of All the Scores in Situation V
Fig.15

MAZE II
Daily Means of All the Scores in Situation I
Fig.16

Daily Means of All the Scores in Situation II
Fig.17

Daily Means of All the Scores in Situation III
Fig.18

Daily Means of All the Scores in Situation IV
Fig.19

Daily Means of All the Scores in Situation V
Fig.20

Legend
——— = P and P' Scores
—·— = A and A' Scores
······ = B and B' Scores
—··— = C and C' Scores
—···— = S and S' Scores
x axis — Experimental Days
y axis — Daily Mean Scores

Chart II.

the onset of the limit of learning. The method resorted to will depend upon an examination of the intercorrelations between individual daily records.

At the limit of learning, the values of the individual discrimination scores ought, from such a point on, to be more or less uniform, while the intercorrelations of daily scores should be at their maximum and remain constant. At the beginning of learning, on the other hand, each rat will be learning at its own rate; and the intercorrelations of daily scores ought therefore to be low. Hence, if the intercorrelations of the scores of the first and second days, of the second and third days, and so on, are surveyed, it should be possible to detect a point at which the intercorrelations become relatively high and remain so. In fact, turning to table 2, such a point appears in situation I on the fifth day in maze I, and on the fourth day in maze II.[3]

TABLE 2

INTERCORRELATIONS OF P SCORES IN MAZES I AND II IN SITUATION I.

Maze	Days	2	3	4	5	6	7	8	9
	1	.16	.16	.15	−.38	−.28	−.31	.13	.07
	2		.33	.46	.43	.34	.34	.37	.05
	3			.49	.28	.08	.17	.08	−.04
I	4				.47	.41	.15	.09	−.06
	5					.61	.50	.18	.20
	6						.54	.31	.25
	7							.61	.44
	8								.67
	1	.06	.57	.20	.07	.10	.13	.22	.02
	2		.53	.27	.05	−.06	−.24	−.09	−.23
	3			.42	−.22	−.14	.24	0	−.48
II	4				.24	.41	.02	.19	.07
	5					.51	.45	.45	.55
	6						.62	.54	.53
	7							.66	.86
	8								.79

[3] All the possible intercorrelations in both mazes, numbering some 5,000, are given in full in the original manuscript. All correlation coefficients were computed by Pearson's formula.

A survey of these intercorrelations shows that the coefficients on the first diagonals are higher than on any other diagonal, and that they increase as one descends along this diagonal. The next best rows are the second diagonals. This shows that, as the learning progresses, the performance becomes more and more stabilized. Similar tables (not here presented) for situations II, III, IV, and V showed the same thing. If we take the averages of the diagonal coefficients of the five situations for each maze, we get the results shown in table 3.

TABLE 3

Days	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9
Maze I..........................	.272	.346	.361	.510	.546	.556	.568	.601
Maze II.........................	.072	.374	.422	.404	.474	.542	.568	.640

Since $n = 20$, these coefficients have to be .40 or more to be significant. Table 3 shows that the coefficients become significant on the fifth day in maze I, and on the fourth day in maze II. This evidence supports the claim set forth in the discussion of the daily average, that on the fifth day a limit of learning is reached.

3. CONDENSED INTERCORRELATIONS

Another way of obtaining evidence from the intercorrelations is to compute the correlations between: (1) scores in the first half and scores in the last half; (2) scores on odd days and scores on even days. For this purpose, the dividing line of the two halves was again placed between the fourth and fifth days, The results by this method are shown in table 4.

The half-vs.-half coefficients of P in both maze I and maze II are relatively low. On the other hand, the odd-day-vs.-even-day coefficients of P in both mazes are relatively high, and probably are as high as one could hope for under the conditions.

The low values of the half-vs.-half coefficients may be explained by saying that the performance in the beginning of learning is different from that near the end of learning. In

how far do the high odd-vs.-even coefficients indicate stable performance throughout? In order to answer this, odd-vs.-even coefficients were computed for the first and last halves separately. Table 4 shows that the odd-vs.-even correlations both in the first four days and in the last five days were satisfactorily high, with the exception of situation II, maze I. Further, it shows that the odd-vs.-even correlations in the last five days are without exception higher than the corresponding ones in the first four days. This indicates that the performance in the last half was more uniform and stable than the performance in the first half, and that learning has ceased to affect the records on the fifth day and thereafter.

TABLE 4

CONDENSED INTERCORRELATIONS OF P SCORES

Situation	Maze I				Maze II			
		Odd vs. even				Odd vs. even		
	Half vs. half†	Whole	First half	Last half	Half vs. half	Whole	First half	Last half
I	.50	.84	.76	.87	.02	.77	.69	.84
II	.43	.91	.02	.83	.43	.94	.76	.85
III	.02	.79	.56	.77	.50	.84	.61	.80
IV	.55	.96	.71	.94	.45	.88	.62	.82
V	.55	.89	.79	.88	.68	.77	.54	.90

* The coefficients are the corrected coefficients by Brown's formula.

† Half vs. half—1, 2, 3, 4 vs. 5, 6, 7, 8, 9 days.

Odd vs. even, whole—1, 3, 5, 7, 9 vs. 2, 4, 6, 8 days.

Odd vs. even, first half—1, 3 vs. 2, 4 days.

Odd vs. even, last half—5, 7, 9 vs. 6, 8 days.

The three factors so considered, namely, the daily averages, the intercorrelations, and the condensed intercorrelations may not, each by itself, justify the division made between the fourth and the fifth days. The daily averages were rather unstable, as shown by the large sigmas; the diagonal intecorrelations included some low coefficients, a sort of inversion of the second order; and the data on the condensed coefficients were divided into the two halves rather arbitrarily. But when the three

results were taken together, the evidence seems to justify th
division made. *On the fifth day we may reasonably assume tha*
the maze has been learned and that the performance on the fift
day and thereafter is one of discrimination and no longer con
taminated by learning.

Proof of Weber's Law —

The main question of the present research can now be pu
specifically as follows: How does the distribution of the frequen
cies of the P scores in the last five days in maze I compare wit
the distribution of the frequencies of the P scores in the sam
period in maze II?

1. COMPARISON OF THE MEANS IN THE TWO MAZES

One way of answering our question is to compare the mean
of the gross scores. In the last five days each rat had 30 chance
to choose (six trials per day for five days), and chose the shor
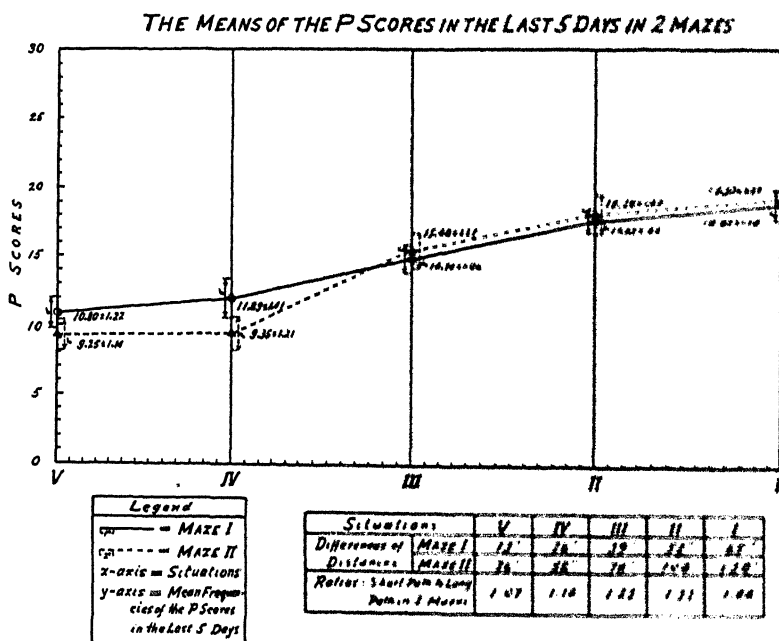
Chart III.

path as many times as is indicated by the sum of the P scores. The individual P scores in maze I in each situation were averaged; and similarly for maze II. The results are shown in table 5 and plotted in chart III. The curves in chart III run

TABLE 5

COMPARISON OF THE MEANS OF P SCORES OF THE LAST FIVE DAYS IN TWO MAZES

Situation	Item	P
I	$M_I{}^*$	18.85
	M_{II}	19.30
	M_I M_{II}	.45
	σ_{diff}†	6.02
II	M_I	17.65
	M_{II}	18.20
	M_I M_{II}	.55
	σ_{diff}	5.67
III	M_I	14.74
	M_{II}	15.40
	M_I M_{II}	.66
	σ_{diff}	4.83
IV	M_I	11.89
	M_{II}	9.35
		2.54
		1.11
V	M_I	10.80
	M_{II}	9.25
	M_I M_{II}	1.55
	σ_{diff}	1.01

* M_I mean score in maze I. M_{II} mean score in maze II.
† $\sigma_{diff} = \sqrt{\sigma M_I{}^2 + \sigma M_{II}{}^2}$

close together. The pairs of means in each situation are not identical, but their differences are small: .45, .55, .66, 2.54, 1.55. The sigmas of these differences are 6.02, 5.67, 4.83, 2.54, and 1.01 respectively. There was therefore no significant difference between the means in any of the five situations.

No other evidence would seem necessary to verify Weber's Law. And yet, unfortunately, it is not statistically valid. The number of subjects in each situation is 20, except in situation III in maze I, where $n = 19$, and in situation IV in maze I, where $n = 18$. The sigmas of means when n is as small as 20 are really much larger than those here calculated. In calculating a sigma of means, certain product terms are considered negligible. But such as assumption is valid only when n is fairly large, say 30 (Kelley, 1923)). Hence, we turn to another method of examining the data.

2. CORRELATION METHOD[4]

The curves of the means in chart III, when superimposed, show divergencies due to their irregular contours. There is a way, however, to straighten these out. The Pearson correlation surface and the principles involved in the formation of such a surface show the way. The differences of length between the short and the long paths were taken as x variates, and the sums of the P scores of the individual rats were taken as y variates. X varies from 13 inches to 65 inches by steps of 13 inches in maze I; it varies from 26 inches to 130 inches by steps of 26 inches in maze II. Y varies from 0 to 30 in both cases. For an individual rat, then, we have two sets of data, its x, differential stimulus (difference of length of the two paths), and y, its gross P score. These were correlated by the Pearson formula for both maze I and maze II, $n = 97$ for maze I and $N = 100$ for maze II.

The correlation coefficient in maze I was found to be .519 ± .074; in maze II it was .579 ± .067. Both are significant coefficients, as shown by the small standard errors, and one lies within the standard error of the other. This fact indicates that the frequency of the choice of the short path depends upon the difference in length between the short and long paths, and not upon the absolute length of the comparison path. The impor-

tance of the distance factor in maze learning is again confirmed, and also the constancy of DL, on whatever basis it is defined.

A regression coefficient of y over x, b_{yx}, which is defined as $b_{yx} = r\dfrac{\sigma_y}{\sigma_x}$ was sought, and found to be $.167 \pm .028$ in maze I, and $.111 \pm .016$ in maze II. Then $y = b_{yx}x$ is the equation of the regression line of y over x. This is the promised straightened

Chart IV.

line for the five scattered means. When the two regression lines are plotted on the same surface (chart IV), with shaded zones indicating the limits of the standard errors, it is evident that the one lies within the standard error limits of the other. In other words, the same relative difference yields the same proportion of correct choices (choice of the short path) with different absolute distances. This is nothing less than Weber's Law.

SUMMARY AND CONCLUSION

1. Maze I was so constructed that two paths visually similar were offered for choice. One path was 211 inches long and kept constant, while the other could be shortened by steps of 13 inches. Maze II was similarly constructed, but magnified by two. Five short paths were used in each maze, giving rise to five comparison situations in which the ratios of the long to the short path were 1.44, 1.33, 1.23, 1.14, and 1.07 respectively. Each rat was offered only one such comparison situation and six trials per day for nine days constituted a rat's experimental program. In maze I, 97 rats were used, distributed approximately equally to the five situations; 100 rats were used in maze II, also equally distributed.

2. Scores were recorded in eight categories: P — choice of the short path; P_{ι} — choice of the long path; A — confused running, with final choice of the short path; A_{ι} — confused running, with final choice of the long path; B — corrected running, with first a choice of the long path and then one retracing, and finally a choice of the short path; B_{ι} — a choice of the short path followed by a retracing and finally a choice of the long path; C — running, disturbed by some external factor resulting in retracing in the short path; C_{ι} — disturbed running with retracing in the long path; $S = A + B + C$, the sum of all the retracing scores ending in the choice of the short path; $S_{\iota} = A_{\iota} + B_{\iota} + C_{\iota}$, the sum of all the retracing scores ending in the choice of the long path.

3. The scores of the first four days were discarded; the scores of the last five days only were considered in the final comparison. The division of scores into these two halves seemed justified by the following facts: (1) the learning curves plotted from the daily averages of P scores (choice of the short path) began to reach a limit on the fifth day; (2) the intercorrelations of the P scores became significant on the fifth day and remained so throughout the rest of the learning period; (3) condensed

intercorrelations were higher in the last five days than in the first four days.

4. The averages of the individual P scores in the last five days in maze I were compared with the averages of the similar scores in maze II for each of the five situations. No significant difference was found for any of the five pairs of means. But because of the small number of cases, the standard errors calculated for these means may not have been correct.

5. The gross P scores for individual rats were therefore plotted for the last five days on the y-axis against the differences of the lengths of the short and long paths on the x-axis. The correlation coefficient thus obtained between P scores and the differences of lengths in maze I was .519 + .074; the similar correlation coefficient for maze II was .579 + .067. When the two regression lines calculated with these coefficients were plotted on the same surface, it was found that one lay within the limits of the standard error of the other. The two regression lines were practically identical.

6. Points 4 and 5 taken together seem to prove that with different absolute distances the same relative difference of distance yields the same proportion of correct choices. This is nothing less than Weber's Law. Therefore it is concluded that Weber's Law holds in the discrimination of maze distances by the white rat within the limits of distance investigated in this experiment.

APPENDIX 1

STATISTICS OF THE CORRELATION METHOD

The use of the correlation method in the treatment of data in the present problem needs consideration because the soundness of the final conclusion rests upon the validity of the statistics employed.

The use of the Pearson correlation coefficient implies that the data are independent (unrelated). This requirement was met by the experimental condition that each rat reacted to only

one comparison stimulus, and so the individual scores were independent of one another. A second requirement is that the correlation must be rectilinear. The test for rectilinearity is made by finding η, the correlation ratio, and further, by calculating ζ, which is defined as $\zeta = \eta^2 - r^2$. The standard error of ζ can be calculated by Blakeman's formula,

$$\sigma\zeta = \frac{2}{\sqrt{\eta}} \sqrt{\zeta(1 - \eta^2)^2 - (1 - r^2)^2 + 1}$$

In the present case, $\zeta = .019 + .023$ in maze I; $\zeta = .031 + .034$ in maze II. Hence it is not significant in either maze, i.e., each correlation is approximately rectilinear.

The other formulae used also rest upon specific conditions. For example, the σ_r formula requires mesokurtic and homoscedactic distribution; the σb_{xy} formula requires homoedisy and rectilinearity in distribution. To save labor, instead of justifying the use of each specific formula, we shall show that the P-score distribution is normal. The normality of distribution may be considered a sufficient guaranty against transgressing violently any of the statistical requirements involved (Kelley, 1923).

The histograms of P distribution in mazes I and II are found in chart V. By inspection both distributions are a little platykurtic and positively skewed. Testing normality in terms of movements, we found: $\beta_1 = .0651$, $\beta_2 = 2.8457$ in maze I; $\beta_1 = .0799$, $\beta_2 = 2.4058$ in maze II. Since a normal curve has $\beta_1 = 0$, $\beta_2 = 3$, these distributions are not very far from normal. In maze I $\beta_2 - 3 = -.1543$; in maze II $\beta_2 - 3 = .5942$. But the sigmas of β_2 of a normal curve with the same number of cases are $\pm .4974$ and $\pm .4899$, in maze I and maze II, respectively. Neither deviation in kurtosis is significant, and the distribution may be considered mesokurtic.

A test for skewness is made in terms of x, when

$$x = \frac{\sqrt{\beta_1(\beta_2 + 3)}}{2(5\beta_2 - 6\beta_1 - 9)}$$

In maze I, $x = .1541$; in maze II $x = .2997$. The sigmas of x of a normal curve with the same number of cases are $\pm .1541$

and $\pm$ .1225 in maze I and maze II, respectively. In neither case is the amount of skewness significant. The normality of the distributions, thus established, guarantees sufficiently the applicability of all the formulae employed.

HISTOGRAMS
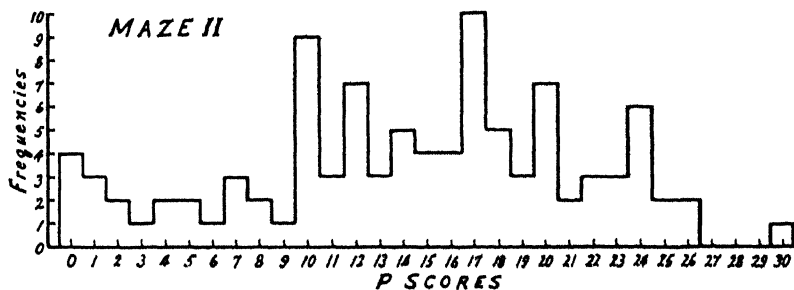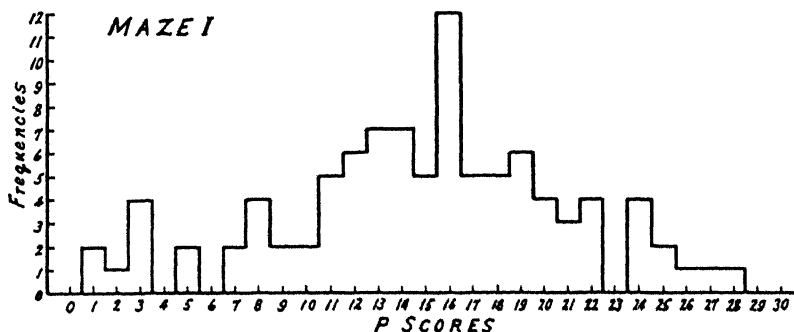
Chart V.

APPENDIX 2

THRESHOLD

The threshold for the discrimination of maze distance was computed in the following manner: it was shown that in the last five days the discriminative scores P and P_c amounted to 73 per cent of the total scores in two mazes. If the choice of P or P_c were determined by chance alone, P would score half of this amount, namely 36.5 per cent; and as the total score

is 30, P would be 11 (36.5 per cent of 30). Any P score higher than 11 can be considered as a score indicating a discriminative choice and the threshold may be placed here. Turning to the correlation surface in chart IV the x value (distance) corresponding to $y = 11$ is found. Dividing this value by the total distance, a *DL* of .10 is obtained.

LITERATURE CITED

CARR, H.
    1917a. "Maze Studies with the White Rat. I. Normal Animals."
        Jour. Animal Behavior, 7:259-275.
    1917b. *Idem*. "II. Blind Animals." *Ibid.*, 277-294.
    1917c. *Idem*. "III. Anosmic Animals." *Ibid.*, 295-306.

DECAMP, J. E.
    1920. "Relative Distance as a Factor in the White Rat's Selection of
        a Path." *Psychobiology*, 2:245-253.

KELLEY, T. L.
    1923. *Statistical Method*, 82-83, 172-179.

KUO, Z. Y.
    1922. "The Nature of Unsuccessful Acts and Their Order of Elim-
        ination in Animal Learning." *Jour. Comp. Psychol.*, 2:1-27.

RICHARDSON, F.
    1909. "A Study of Sensory Control in the Rat." *Psychol. Mono-
        graphs*, 12:124.

RICHTER, C. P.
    1922. "A Behavioristic Study of the Activity of the Rat." *Compara-
        tive Psychology Monographs*, 1:2-55.

SLONAKER, J. R.
    1912. "The Normal Activity of the White Rat at Different Ages."
        Jour. Comp. Neur. and Psychol., 17:342-359.

VINCENT, S. B.
    1915a. "The White Rat and the Maze Problem. I. The Introduction
        of a Visual Control." *Jour. Animal Behavior*, 5:1-24.
    1915b. *Idem*. "II. The Introduction of an Olfactory Control." *ibid.*,
        140-157.
    1915c. *Idem*. "III. The Introduction of a Tactual Control." *ibid.*,
        175-184.

WATSON, J. B.
    1907. "Kinaesthetic Sensations." *Psychol. Rev. Monographs, Suppl.*,
        33.

YERKES, R. M.
    1907. *The Dancing Mouse*, 1-124.
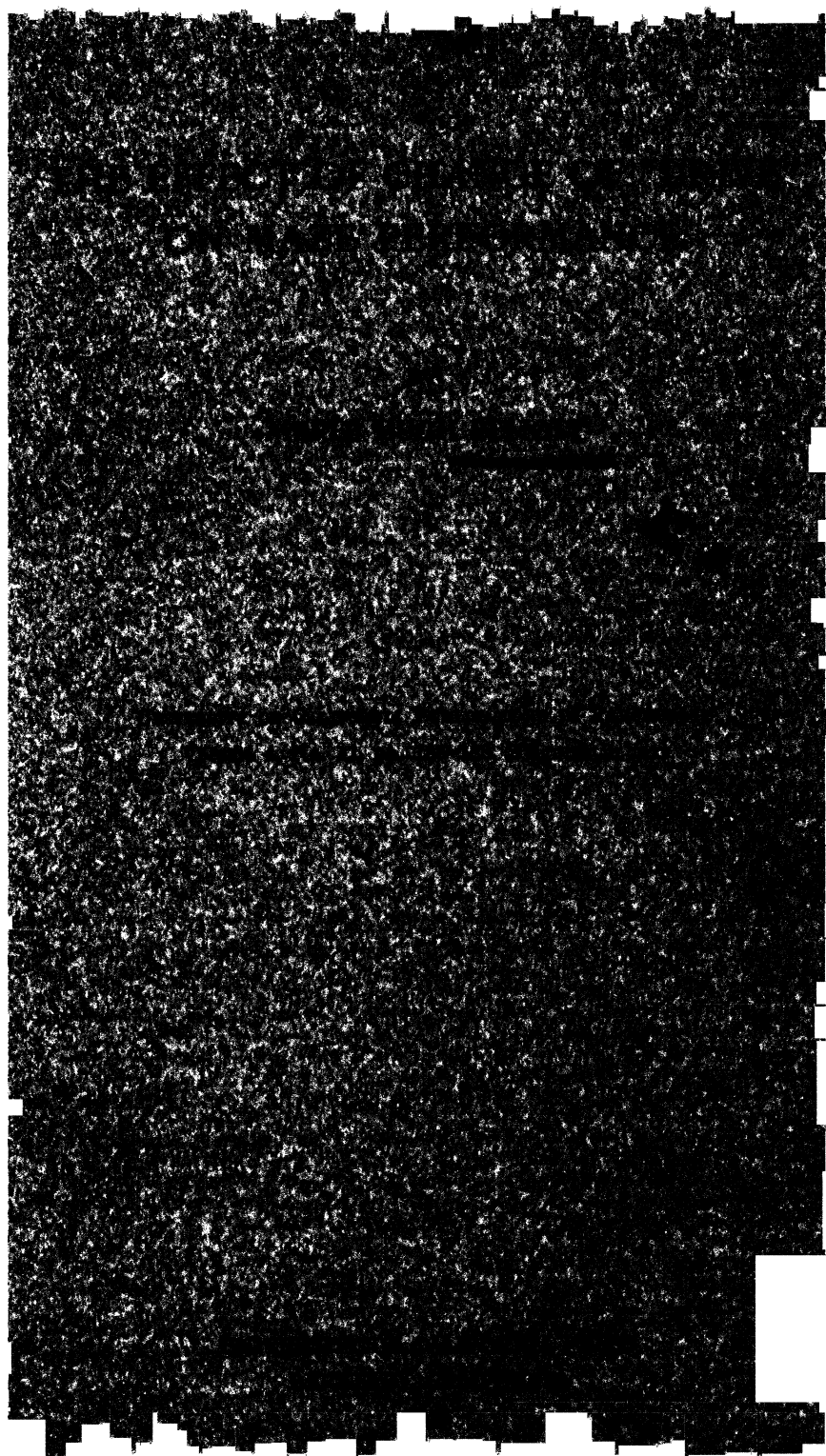
THE EFFECT OF CHANGE OF "DRIVE" ON MAZE PERFORMANCE[1]

BY

MERLE HUGH ELLIOTT

The experiment here reported constitutes a continuation of earlier studies[2] and makes use of the same maze and general technique. These studies are part of a program of research the general object of which is the analysis of motivation and the determination of its operation in maze performance.

An experimental group of 34 rats were given one trial per day in the fourteen-blind multiple-T maze. For the first nine days these rats were "thirsty"[3] when put in the maze and were rewarded with water at the end-box. On the tenth day and thereafter they were hungry (but not thirsty) when put in the maze and were rewarded with a standard mixed diet.

A control group of 32 rats remained on the thirst and water-reward program throughout the training period.

The error data and the time data are depicted graphically in figures 1 and 2 respectively. Tables 1 and 2 present the means represented in the curves.

In order to show the significance of the differences of the means of the two groups for the various days, table 3 presents for each day the ratio of the difference of the means to the standard deviation of that difference (i.e., $\dfrac{\text{Diff.}}{\sigma_{\text{diff}}}$).

[1] "Drive" is used, rather arbitrarily to mean the internal condition resulting from deprivation of food or water.

[2] Elliott, M. H., "The Effect of Change of Reward on the Maze Performance of Rats," *Univ. Calif. Publ. Psychol.* (1928), 4:19–30.

Elliott, M. H., "The Effect of Appropriateness of Reward and of Complex Incentives on Maze Performance," *Univ. Calif. Publ. Psychol.* (1929), 4:91–98.

[3] "Thirst" and "hunger" are used as synonomous with "drive" and imply nothing as to mental content.
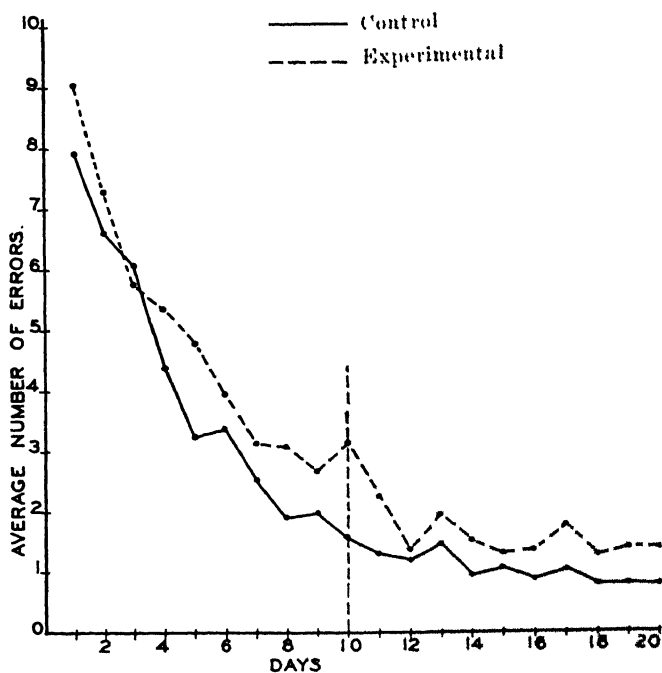
Fig. 1

TABLE 1

AVERAGE NUMBER OF ERRORS PER DAY

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Experimental group	9.03	7.53	5.74	5.35	4.68	3.91	3.09	3 06	2 62	3 18	2 26	1 32	1 91	1 47	1 32	1 41	1 76	1 21
Control group	7.94	6.66	6.03	4.31	3.28	3 38	2 56	1 91	1 94	1 59	1 31	1 19	1 44	97	1 11	97	1 03	84

TABLE 2

AVERAGE TIME (SECONDS) PER DAY

Days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Experimental group	423.9	176.2	107.5	103.9	82.1	74.2	70 4	61 7	65 0	81 7	48 7	47 7	45 2	38 3	41 0	17 8	41 7	35 7
Control group	318.4	148.5	111.0	99.7	86.5	84.3	76 7	53 7	46 2	53 4	39 3	53 9	54 7	43 0	17 7	41 1	40 7	40 8

The change in conditions on the tenth day caused an increase in the average time and errors of the experimental group which may be attributed to "expectation" of a reward unsuited to the new drive (i.e., hunger). As soon as the new and now
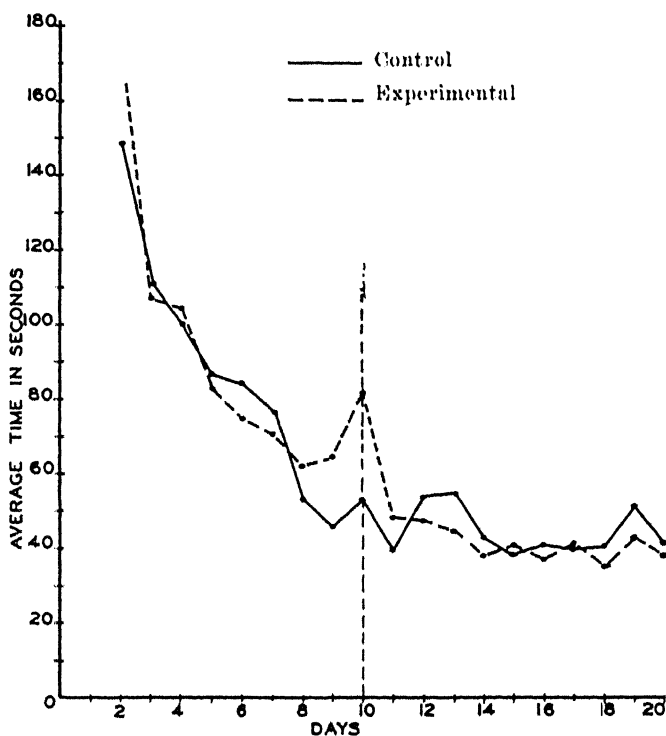
Fig. 2

TABLE 3

RELIABILITIES OF THE DIFFERENCES BETWEEN THE MEANS OF THE
EXPERIMENTAL AND CONTROL GROUPS

Days	8	9	10	11	12	13	14	15	16	17	18
Diff. errors σdiff.	2 31	1 37	3 30	2 49	.39	.95	1 27	.63	1.46	1.81	1 25
Diff. time σdiff.	98	1 95	2 25	1 57	.63	.95	.51	.52	.60	.16	.84

appropriate reward was discovered, the learning curve resumed its downward course and continued just as though there had been no change of drive and reward.

It is concluded that rewards may be changed without materially affecting the learning curve, provided that the drive is changed so as to maintain an "appropriate" relationship between drive and reward.

THE EFFECT OF DEGREES OF HUNGER
UPON THE ORDER OF ELIMINATION
OF LONG AND SHORT BLINDS

BY

E. C. TOLMAN, C. H. HONZIK, AND E. W. ROBINSON

THE EFFECT OF DEGREES OF HUNGER
UPON THE ORDER OF ELIMINATION
OF LONG AND SHORT BLINDS[1]

BY

E. C. TOLMAN, C. H. HONZIK, AND E. W. ROBINSON

INTRODUCTION

In an experiment on the effect of length of blind alleys in maze learning, Peterson[2] came to the conclusion that "entrances to short *culs de sac* are eliminated more readily, other things equal, than entrances into long ones." White and Tolman,[5] in a further study of the same problem, came to the opposite conclusion, namely, "that in certain types of situations at least, long blinds and not short ones are eliminated first." Since it was objected by Peterson[3] "that the White-Tolman conclusion was based on only 342 single errors of 14 rats," it was decided to repeat the experiment with a larger number of animals and with two types of maze, one in which the blinds were without elbows and one in which the blinds had elbows; and, further, to determine what effect different degrees of hunger might have on the relative eliminations of the two kinds of blinds.

EXPERIMENT I. ELBOWLESS BLINDS

PROCEDURE

Apparatus and animals.—The maze used in this first experiment was a "three-choice" box with the true path straight ahead and with the blinds on either side (fig. 1). Black cloth curtains were placed at the entrance to each path so that the rats could

not see from the entrances the respective lengths of the two
blinds or of the true path. The long blind could be placed either
to the right or to the left. In each group of rats approximately
half the number were run with the long blind to the right and
half with the long blind to the left. This was to eliminate any
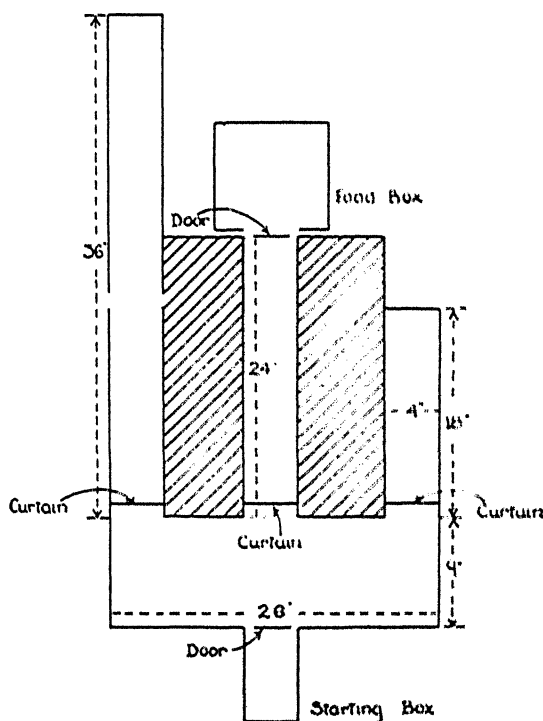
Fig. 1

influence that walls and other physical features of the laboratory
room might have toward favoring one blind more than the other.

Two groups of rats were run, a hungry group and a less
hungry group. Each group contained 40 rats. But in order to
compare directly the results obtained here in Experiment I with
those obtained in Experiment II (in which there were 42 rats in
each group) the data obtained in Experiment I have been multi-
plied in each case by a factor, 1.05, to increase them for each

group to what they presumably would have been for groups of 42 rats. The rats of the hungry group were fed sparingly, so that each rat lost weight (4 to 50 grams) during the whole course of the experiment. The rats of the less hungry group were fed sufficiently to increase weight (5 to 28 grams) during the experiment.

The rats were of a mixed white and black breed from the Department of Anatomy of the University of California: some individuals were white, some black, others hooded. The different coat colors were about equally distributed among the different groups. The rats were all males, approximately three months old at the beginning of the experiment, and they had had no previous training of any sort.

Training.— All animals were first given a preliminary training to accustom them to running in alleys. This consisted of two runs a day for each rat for four days in a "straightaway" provided with curtains, a starting box at one end, and a food box at the other.

In the experiment proper the rats were given one trial a day for five days in the maze as shown. The total daily food ration was given each animal at the completion of the day's run.

Data.— The entrances into the blinds were recorded as follows: An entrance just beyond the curtain but no farther was called "long (blind) 1," or "short (blind) 1." An entrance halfway into the long blind was called "long 2," and full entrance into the short blind was called "short 2." A full entrance to the end of the long blind was indicated by "long 3." Finally, for some of the learning curves all the entrances into a particular blind, e.g., "long 1," "long 2," and "long 3," were lumped and called "long entrances (any degree)," or "short entrances (any degree)."

In any given trial there might be several entrances into either blind before the animal chose the true path. These were all included in the data.

Results

The total number of long blind entrances (of any degree) plus short blind entrances (of any degree) on each day for the entire group was found and considered as 100 per cent. The percentage, on each day, of long entrances (of any degree) and

TABLE 1

Maze with Elbowless Blinds

	Hungry group			Less hungry group		
	Per cent long (any degree)	Per cent short (any degree)	Sigma	Per cent long (any degree)	Per cent short (any degree)	Sigma
Day 1	47.0	53.0	5.5	54.6	45.4	5.4
Day 2	43.1	56.9	6.4	52.6	47.4	5.6
Day 3	54.1	45.9	6.3	68.5	31.5	6.3
Day 4	52.8	47.2	8.3	60.9	39.1	7.2
Day 5	56.7	43.3	8.1	70.2	29.8	6.0
All 5 days	49.8	50.2	3.0	61.3	38.7	2.6
	Per cent "long 1"	Per cent "short 1"	Sigma	Per cent "long 1"	Per cent "short 1"	Sigma
Day 1	71.4	28.6	17.0	76.5	23.5	10.3
Day 2	100.0	00.0	0.0	94.4	5.6	5.4
Day 3	100.0	00.0	0.0	68.2	31.8	9.9
Day 4	100.0	00.0	0.0	70.6	29.4	11.0
Day 5	66.7	33.3	27.2	76.9	23.1	3.7
All 5 days	82.3	17.7	9.3	77.0	23.0	4.7
	Per cent "long 3"	Per cent "short 2"	Sigma	Per cent "long 3"	Per cent "short 2"	Sigma
Day 1	38.8	61.2	5.9	43.6	56.4	5.6
Day 2	38.0	62.0	6.8	43.8	56.2	6.5
Day 3	50.0	50.0	6.9	48.6	51.4	8.4
Day 4	51.4	48.6	8.4	45.7	54.3	8.4
Day 5	48.6	51.4	8.4	50.0	50.0	8.5
All 5 days	44.3	55.7	3.2	45.6	54.4	3.2

of short entrances (of any degree) of this total daily number was then calculated. A similar procedure was carried out for "long 1" and "short 1" and for "long 3" and "short 2" en-

trances.[2] These percentages for both the hungry and the less hungry groups are given in table 1. The sigmas of the percentages are given immediately following the percentages.[3]

The first fact to be noted in an examination of these percentages is that no blanket statement which would hold throughout for all the percentages, can be made. Considering the hungry group by itself, we note that only in regard to "long 1" entrances as compared with "short 1" entrances is there an unmistakable preponderance of "long 1" over "short 1" entrances, i.e., into the short blind there were fewer entrances just beyond the curtain. The same fact holds for the less hungry group, but with the further fact that in the less hungry group there were on each day more long entrances of any degree than short entrances of any degree, i.e., the less hungry rats made more entrances of any and all sorts into the long blind than into the short. This was not true of the hungry rats.

Learning curves based on the absolute numbers (not percentages) of entrances of any degree into the long blind and into the short blind are shown in figure 2, and similar curves for "long 1," "short 1," "long 3," and "short 2" entrances in figure 3.

Considering the curves of the *hungry* group by itself in figures 2 and 3, we note that there seems to be no significant difference between the long and the short blind for full entrances, i.e., "long 3" and "short 2," and for long and short entrances of any degree. In the case of partial entrances, however, i.e., "long 1" and "short 1," there are fewer short blind entrances than long blind entrances, and in this last point Peterson's conclusion that entrances to short *culs de sac* are eliminated more readily than entrances into long ones, seems to be verified. This is true, however, only for this one type of entrance.

---

[2] Percentages were not calculated for "long 2" entrances since these were relatively few in number and had no corresponding type of short entrance with which to be compared.

[3] These sigmas were computed by the formula $\sigma = \sqrt{\dfrac{pq}{n}}$. See Holzinger.[1]

Comparing now the results for the hungry group with those for the less hungry group (figs. 2 and 3), some interesting points appear. In the case of "long 1" entrances as compared with "short 1" entrances, and long entrances of any degree as compared with short entrances of any degree, we find that for the less hungry group "long 1" entrances and long entrances of any degree are more numerous than the corresponding short entrances. Also, considering long entrances by themselves, we see
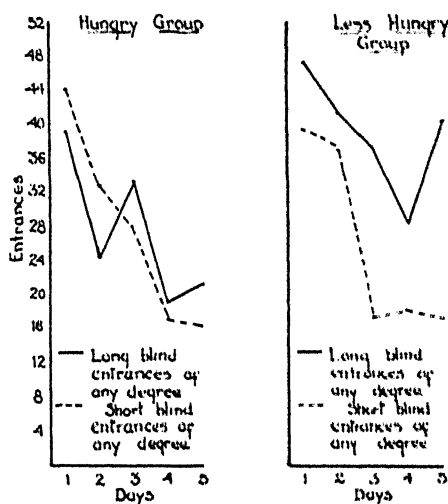
Fig. 2

that long entrances of all the *three* sorts, i.e., "long 1," "long 3," and "long of any degree" are more numerous for this less hungry group than those for the hungry group. Decrease in hunger seems to have had for its result in every case an increase in the number of long blind entrances and a small decrease (in two cases) of short blind entrances. In other words, *it is with the less hungry rats that Peterson's dictum appears to hold.*

This fact that decrease in hunger causes an increase in long blind entrances relative to short blind entrances we would explain, as previously suggested by Tolman,[46] by the somewhat

anthropomorphic (or at any rate purposive) concept that de-
crease in hunger increases random curiosity and that random
curiosity found the long blind more rewarding than the short
blind.
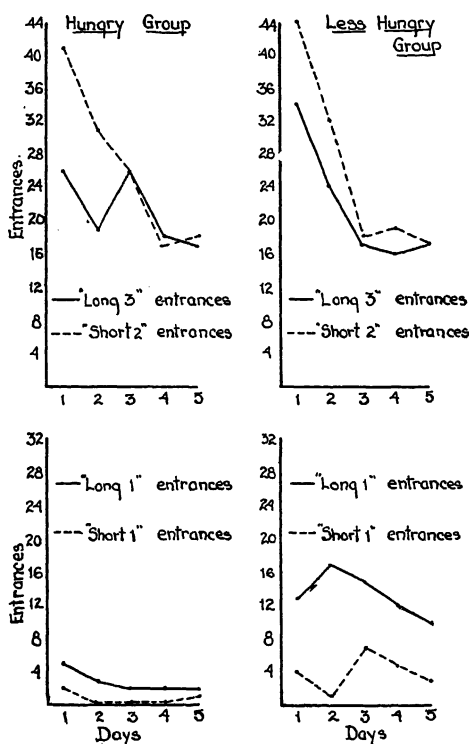
Fig. 3

It is difficult to explain the exception seen in the case of
"long 3" and "short 2" for the less hungry group where "long
3's" are slightly fewer than "short 2's." It seemed possible
that the nature of the blinds might have something to do with
this. To test this, and in order further to verify the other con-
clusions of Experiment I, Experiment II, using a maze with
elbows in the blinds, was carried out.

EXPERIMENT II. BLINDS WITH ELBOWS

PROCEDURE

Apparatus and animals.—The maze used is shown in figure 4. This maze had curtains just beyond the elbows in the blinds as well as at the entrances to the blinds. As in the previous maze, the long blind could be placed either to the right or to
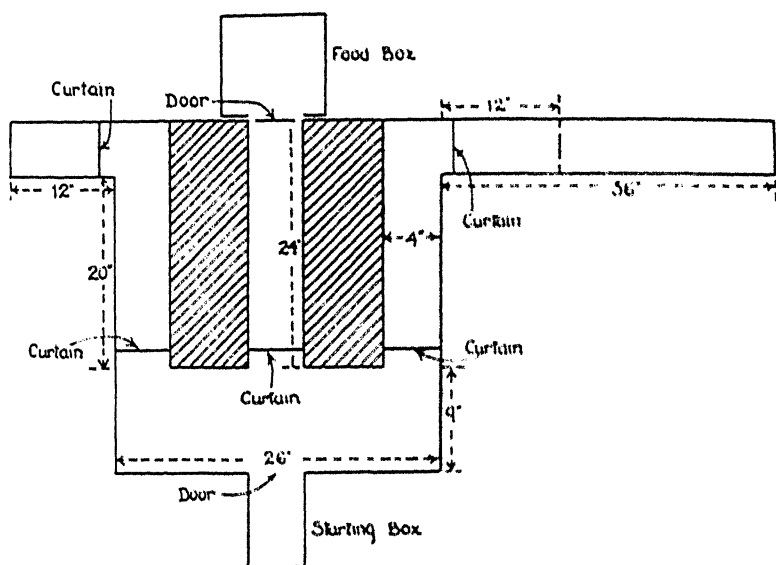
Fig. 4

the left. Approximately half the rats of each group were run with the long blind to the right and half with the long blind to the left, as in Experiment I.

The rats were again all males approximately three months old, of mixed coat color, and without previous training of any sort. The hungry and less hungry groups each consisted of 42 rats. Feeding was the same as in Experiment I ; losses in weight of the hungry rats, and gains in weight of less hungry rats were similar for the two experiments.

Training.—The general training procedure was the same as for Experiment I, with the same preliminary training in the "straightaway," but the experiment proper consisted of one trial a day for ten days, instead of five days as in Experiment I.

Data.—Entrances into the blinds were indicated as follows: entrance into the long or short blind just beyond the first curtain but no farther was called "long 1," and "short 1," respectively. Entrances to the end of the long blind and to the end of the short blind were indicated by "long 3" and "short 2." And, as in Experiment I, entrances of any degree into the long or the short blind were lumped for some of the learning curves and were called "long entrances (any degree)" and "short entrances (any degree)."

RESULTS

Percentages of "long 1," "long 3," and long entrances of any degree, calculated as in Experiment I, are given in table 2.

Considering first the *hungry* group, it will be noticed that in the case of long entrances of any degree as compared with short entrances of any degree the long entrances are more numerous on seven days of the ten, as contrasted with the similar group of Experiment I which showed a fairly equal distribution of long-blind and short-blind entrances. Further, we notice for this group in regard to the "long 1" and "short 1" entrances that the order has been reversed, "long 1" entrances being distinctly fewer on nine days than the "short 1" entrances. In other words, Peterson's conclusion, which seemed to be verified for this type of entrance in Experiment I, is here controverted.

With the *less hungry* group of rats the outstanding fact is in regard to "long 3" and "short 2" entrances, the former being more numerous on all ten days. This is a reversal of the results of Experiment I and is most probably due to the different type of blind used in Experiment II.

Learning curves based on the absolute numbers of "long 1," "long 3," and long entrances of any degree are shown in figures

TABLE 2

Maze with Elbow Blinds

	Hungry group			Less hungry group		
	Per cent long (any degree)	Per cent short (any degree)	Sigma	Per cent long (any degree)	Per cent short (any degree)	Sigma
Day 1	51.4	48.6	4.2	53.4	46.6	4.1
Day 2	48.4	51.6	5.1	56.4	43.6	4.9
Day 3	50.7	49.3	6.1	56.0	44.0	4.6
Day 4	45.6	54.4	7.3	54.9	45.1	4.9
Day 5	45.6	54.4	6.6	54.6	45.4	4.8
Day 6	44.2	55.8	7.5	56.5	43.5	5.2
Day 7	28.6	71.4	8.5	58.8	41.2	4.6
Day 8	41.2	58.8	11.9	55.8	44.2	5.6
Day 9	45.9	54.1	8.2	55.6	44.4	4.6
Day 10	50.0	50.0	10.7	56.2	43.8	4.8
All 10 days	47.3	52.7	2.0	55.6	44.4	1.4
	Per cent "long 1"	Per cent "short 1"	Sigma	Per cent "long 1"	Per cent "short 1"	Sigma
Day 1	39.6	60.4	7.1	48.0	52.0	10.0
Day 2	36.4	63.6	8.4	45.8	54.2	10.1
Day 3	44.0	56.0	9.9	41.7	58.3	8.2
Day 4	39.1	60.9	10.1	45.0	54.0	7.8
Day 5	36.4	63.6	10.2	52.2	47.8	7.3
Day 6	34.8	65.2	9.9	57.5	42.5	7.8
Day 7	20.0	80.0	10.3	54.5	49.5	7.8
Day 8	40.0	60.0	15.5	58.3	41.7	8.2
Day 9	27.8	72.2	10.5	43.2	56.8	7.5
Day 10	50.0	50.0	17.7	45.2	54.8	7.7
All 10 days	36.9	63.1	3.2	49.3	50.7	2.6
	Per cent "long 3"	Per cent "short 2"	Sigma	Per cent "long 3"	Per cent "short 2"	Sigma
Day 1	56.2	43.8	5.3	51.1	48.9	4.2
Day 2	51.7	48.3	6.5	58.3	41.7	5.4
Day 3	58.5	41.5	7.7	60.0	40.0	5.3
Day 4	50.0	50.0	10.2	63.9	36.1	5.6
Day 5	48.5	52.5	8.8	58.9	41.1	5.7
Day 6	61.1	38.9	11.5	60.0	40.0	6.1
Day 7	42.8	57.2	13.2	64.1	35.9	5.4
Day 8	50.0	50.0	15.8	59.7	40.3	6.0
Day 9	55.5	44.5	11.7	58.2	41.8	5.2
Day 10	53.8	46.2	13.8	65.4	34.6	5.3
All 10 days	53.7	46.3	2.8	59.2	40.8	1.7

5 and 6.   These curves are drawn in the same fashion as the
corresponding ones of Experiment I.

Examining the curves for the *less hungry* group, we observe
that the general conclusion from Experiment I as to the effect
of decreasing hunger is even more strongly supported by these
results of Experiment II.   Particularly is the effect of decreased
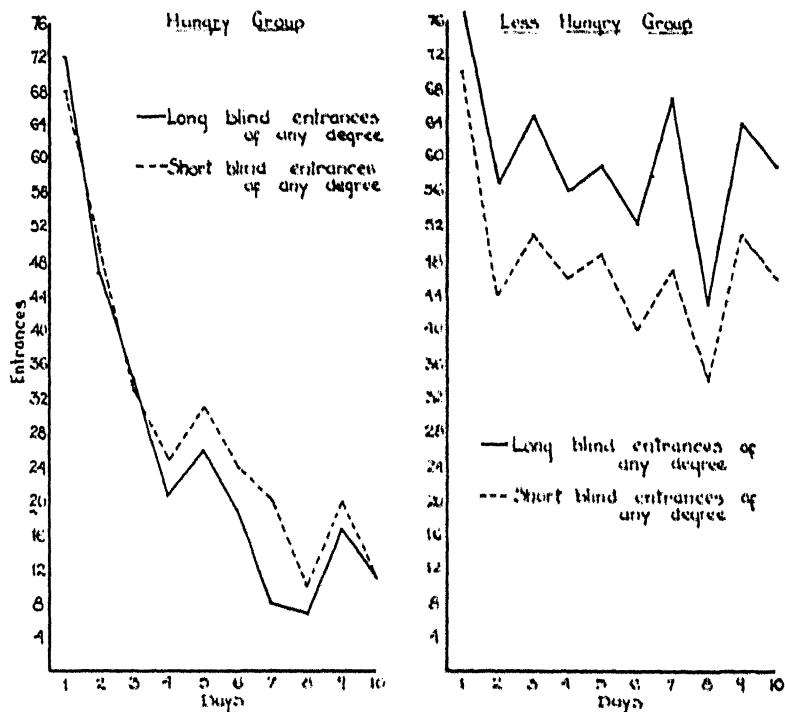
Fig. 5

hunger upon increasing long-blind entrances apparent for the
full entrances, i.e., "long 3's."   This is what should be ex-
pected from the theory, for if an excess of long-blind entrances
is primarily a product of random curiosity, then blinds with
elbows, and where the excess of the long blind is beyond the
elbow, should emphasize this phenomenon.

An implication of the hypothesis advanced by White and
Tolman[5] would be that, if the rat is *very hungry*, the longer

the blind the worse it is and the sooner eliminated.   This is
borne out by the data for the *hungry* group on "long 1" as
compared with "short 1" entrances, and on long entrances of
any degree as compared with short entrances of any degree,
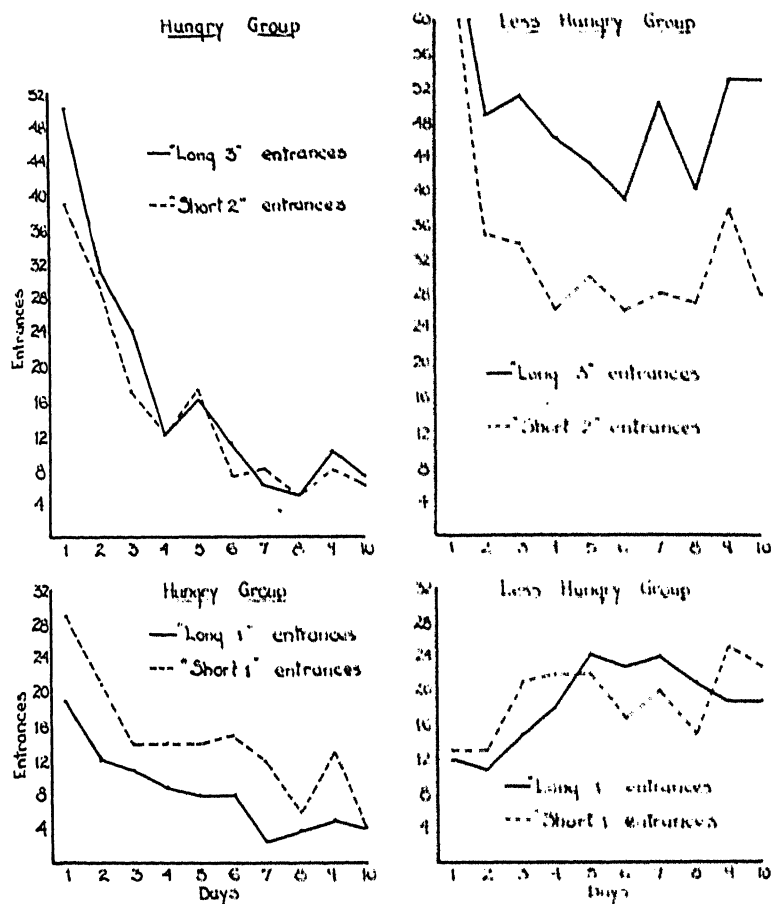
Fig. 6

the long entrances being fewer in both cases.   But this does
not hold for "long 3" as compared with "short 2" entrances
where the two sorts of entrances are about equal in numbers.
This exception may perhaps be explained by the observed fact
that, once the rat peeped beyond the second (i.e., the elbow)

curtain of the long blind, he was very apt to run to the end of that blind, there being no clearly visible obstruction. This was not the case with the short blind where the end was apparently clearly visible, once the rat peeped beyond the curtain.

On the other hand, the fact that considerably fewer *attempts* were made by the hungry rats to enter the long blind than the short blind, as is shown by the curves for "long 1" and "short 2" (fig. 6), argues strongly for the hypothesis, that for a hungry rat a long blind is more disagreeable than a short one and is therefore more readily eliminated.

In order to discover something about the statistical significance of these results in Experiment II we worked out the "critical ratio" for the following pairs of entrances: for the less hungry group, "long 3" and "short 2," and long entrances of any degree and short entrances of any degree; and for the hungry group, "long 1" and "short 1" entrances. These ratios were calculated by finding the sigmas of the means of the long entrances and of the short entrances of the entire group of rats and applying the usual formula. Due consideration was given to the fact that long and short entrances are correlated in a particular group. The ratios follow:

<div align="center">TABLE 3</div>

	Critical ratio
Less hungry group:	
"Long 3" vs. "short 2"	4.677
Long (any degree) vs. short (any degree)	3.12
Hungry group:	
"Long 1" vs. "short 1"	.80

It appears that the differences between the members of the pairs of entrances mentioned are too large to be accounted for by pure chance.

SUMMARY AND CONCLUSION

When the rats were relatively hungry there was not much difference in number between long-blind entrances and short-blind entrances in a maze with elbowless blinds. But when the blinds had elbows the long-blind entrances were fewer than the short-blind entrances. If the rats were less hungry all entrances tended to increase in number, but the long-blind entrances increased more than the short-blind entrances. This greater increase was particularly evident when the blinds had elbows.

To explain these results we suggest two complementary hypotheses: (1) *For hungry rats the long blind, since it causes more delay, is more disadvantageous than the short, and therefore tends to be eliminated first. This is more evident in a maze with blinds having elbows than in one having elbowless blinds.* (2) *For less hungry rats the long blind, offering more opportunity for random curiosity, is more distracting than the short blind and therefore tends to be eliminated less readily. This reverse effect is also more pronounced in a maze with blinds having elbows than in one with elbowless blinds.*

REFERENCES

[1] HOLZINGER, K. J.
   1928. *Statistical methods for students in education*, p. 248.
[2] PETERSON, JOSEPH.
   1917. "The effect of length of blind alleys on maze learning." *Behavior Monographs*, 1: No. 4.
[3] 1924. "White and Tolman on the elimination of short and long blind alleys," *Jour. Comp. Psychol.*, 4:443–445.
[4] TOLMAN, E. C.
   1928. "Habit formation and the higher mental processes in animals," *Psychol. Bull.*, 25:24–53.
[5] WHITE, A. E., and TOLMAN, E. C.
   1923. "A note on the elimination of short and long blind alleys," *Jour. Comp. Psychol.*, 3:327–331.

THE EFFECT OF REMOVAL OF REWARD ON THE MAZE PERFORMANCE OF RATS

BY

ROBERT HALL BRUCE

Price per volume, $3.50.

THE EFFECT OF REMOVAL OF REWARD ON THE MAZE PERFORMANCE OF RATS

BY

ROBERT HALL BRUCE

PROBLEM

Rats were trained in a maze with food as a reward, and on the eleventh day, and thereafter, one group found no food after the run, whereas the remaining group found food throughout the experiment. The problem was to investigate whether the removal of reward affected maze performance.[1]

PREVIOUS STUDIES

Blodgett (1929) ran hungry rats under non-reward conditions. There was little apparent learning until the introduction of a reward, when both time and error curves immediately dropped.

Elliott (1928) changed the reward from bran mash to sunflower seed before the maze was entirely learned. The error and time scores increased.

Elliott (1929a) with three groups of rats, changed the reward from food to water. The first group, very hungry and also very thirsty, when the reward was changed from food to water showed an increase in both time and errors, and then returned approximately to their former level of efficiency. The second group, very hungry but only slightly thirsty, when the reward was

changed showed a rise in time scores. The third group, slightly hungry and very thirsty, when the reward was changed showed a decrease in both time and error scores.

Elliott (1929b) in another experiment, for nine days trained thirsty rats to run the maze with water as a reward. On the tenth day and thereafter, they were hungry (but not thirsty) when put into the maze, and were rewarded with food. On the first day of the change the error and time scores advanced slightly, but on the second day the rats' performance dropped to its previous level.

Grindley (1929), working with chicks, found an increase in the speed of learning with an increase in reward. Chicks that could see a reward but could not get it, improved for a few trials and then retrogressed.

Hamilton (1929), also working with rats, found that a delay between the reaching of the goal box and the receiving of food retarded learning.

Sharp (1929), in a study published after the completion of the present one, working with albino rats, found that when the food incentive was removed there was a marked disintegration of the maze habit. When the food incentive was removed and the number of trials per day increased, there was a variable and marked degree of disintegration.

Simmons (1924) ran different groups of rats with varying combinations of motive and reward, and found that some of these combinations resulted in more rapid learning, in terms of errors, than did others.

Szymanski (1918), varying the degree of hunger but keeping the feeding conditions constant, found that rats not hungry would make an imperfect performance even though previously, when hungry, they had made a perfect performance.

Tolman and Honzik, in an experiment as yet unpublished, compared the maze performance of four groups of rats, varying the degree of hunger and the reward. One group, less hungry and not rewarded, did the poorest; another group, hungry and rewarded, did the best. The less hungry and rewarded group,

and the hungry but not rewarded group, were better than the less hungry but not rewarded group, and poorer than the hungry and rewarded group.

Tolman, Honzik, and Robinson (1930) compared the behavior of very hungry and less hungry rats with respect to long and short blinds. They found that the more hungry rats eliminated the long blinds earlier, and the less hungry rats eliminated them later.

Washburn (1926), working with mice, divided them into hunger-driven and activity-driven groups on the basis of general performance in running and readiness to eat. She found that the hunger-driven group was better at avoiding blinds than the activity-driven group.

Williams (1929) experimented with a "conditioned" goal object. She first taught her rats to find food in a black-white discrimination box. She then ran these rats in a maze and, when the maze was partly learned, introduced this box, but now without food in it, as the goal. These rats, which until then had received no reward, improved their performance for a few trials, but reverted to their previous poor level when there was no reënforcement of the box as a reward object.

PROCEDURE

Maze.—The maze was a square with glass sides covered on the outside by brown paper. It was uniformly lighted from above. Olfactory cues were eliminated as far as possible by frequent brushing of the floor, which was covered with green oilcloth. The top was covered with wire mesh. Each outer side was 52½ inches long and the runways and doors were 4 inches wide. The doors were made of tin; by an arrangement of pulleys the experimenter could open them before the animal and close them after him. The following diagram (fig. 1) presents a plan of the maze, and also indicates the arrangement of the sliding food boxes with compartments for six rats. By means of this arrangement each rat could have its entire day's feeding in a

compartment of the box. When the experimental group was changed into a non-reward group, an entirely new box of the same specifications and material was used.

Animals.—Untrained male rats were used, about half of which were albino and half were hooded, all of them being approximately three months old at the beginning of the experiment.
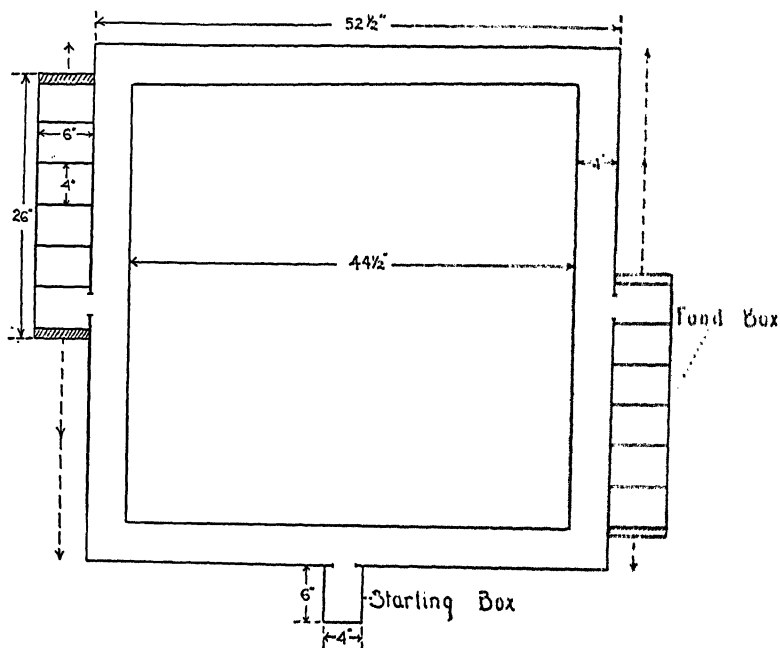
Fig. 1

Method.—Twenty-eight rats were used. After three days of training in a straight runway, so as to accustom them to being handled and to receiving food at the end of the run, they were put into the maze. They were all given one trial each day. At the end of the run they found food in the box and were allowed to remain there until they had consumed their usual daily ration. The food consisted of wet mixed mash, a modification of the Steenbock diet, and was supplemented about twice a week

throughout the experiment by a few lettuce leaves. Water was kept in the cages at all times.

The rats were divided into two equal groups, an experimental and a control group. The experimental group was trained to go to one side of the maze and the control group to the other. On the eleventh day and thereafter, the experimental group found no food in the box, but they were subsequently fed, six hours later, in their cages. This group was cut from fourteen to twelve rats by the death of two from undetermined causes. On the twenty-third day, the afternoon feeding was omitted, and food was not given until after the trial of the following day. The fourteen control rats were fed in the food box throughout the twenty-six successive days of the experiment.

Scoring.—In addition to the time scores, it was noted whether the animal took the long or short path to the food box, and also *how much* excess distance was covered in reaching the box. In computing excess distance the maze was divided into eight sections, two on each of the four sides. If the animal made the correct turn at the start, did not retrace, and immediately entered the food box, it covered two units of maze with no excess distance. If the animal took the wrong turn at the start, taking the long route to the food box, it would cover six units of maze, four units of which would be excess distance. This measure kept account of all retracing. If an animal went into a unit the length of its body, or more, a half-unit was scored; if it went more than halfway into the unit, a full unit was counted. By inspection of figures 2, 3, and 4, and table 1, it can be seen that the percentage of long and short paths taken is a rough and less precise measure of approximately the same thing as excess distance. Both measure the ''knowledge of the maze,'' but the measure of excess distance also takes into consideration the continued searching activity of the organism.

RESULTS

For the first eleven days both groups showed the normal learning curve. In order to determine whether the two groups were comparable, the mean of each group for the eleven days preceding the removal of reward was calculated, and the differ-
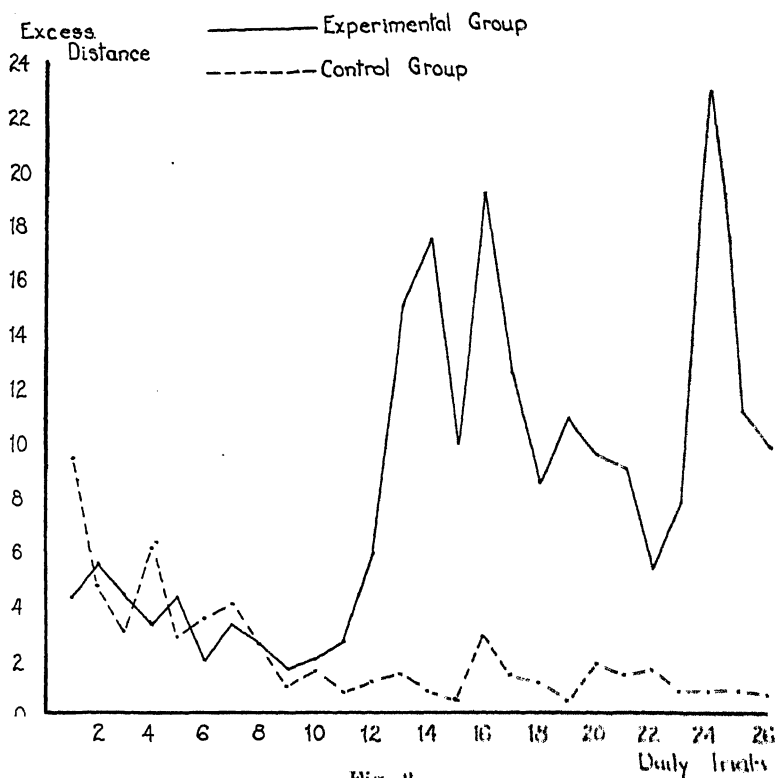
Fig. 2

ence between the means of the two groups was tested to see whether it was significantly different from zero. This was done by dividing the difference by its standard deviation, i.e.,

$\dfrac{Diff.}{\sigma\;diff.}\Big)$, which yielded a value of .522. This value, the critical
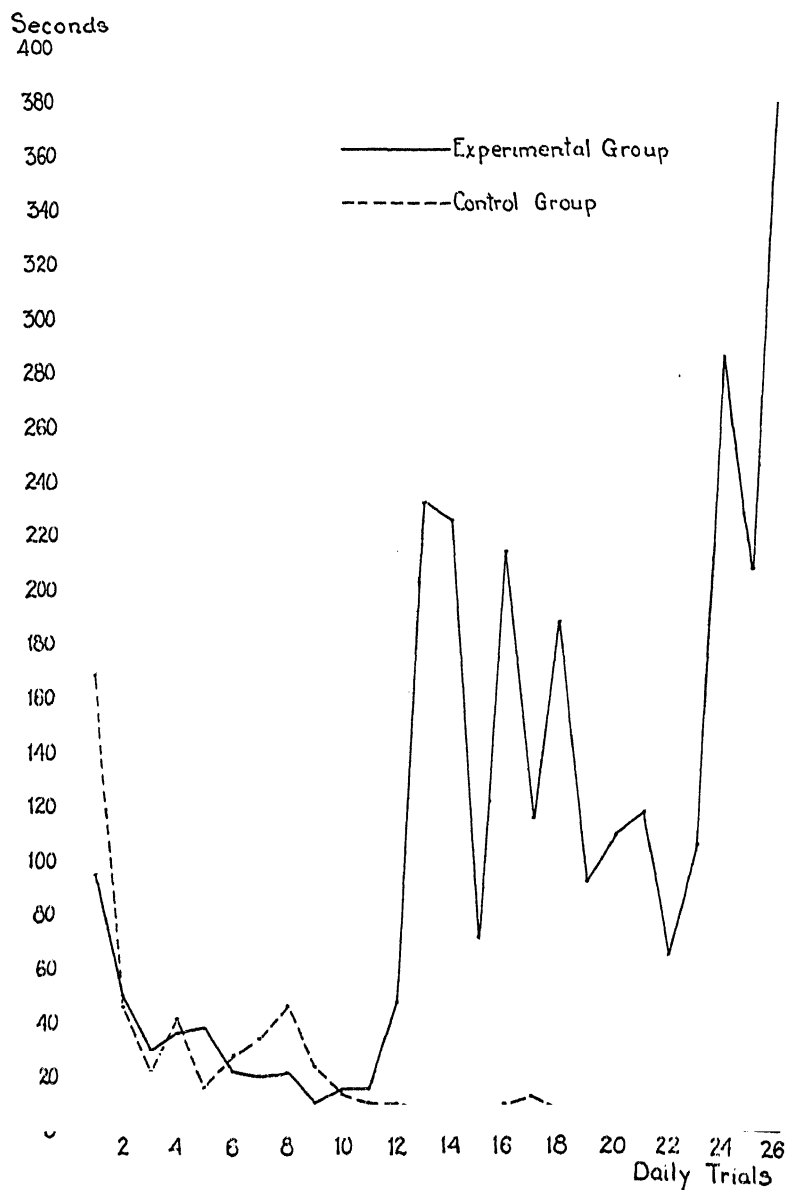
Fig. 3

ratio, indicates that the difference between the two groups cannot be considered to be a significant difference, and hence they can be considered comparable. On the eleventh day the experimental group found no food in its box. This change was followed for three days by an increase in time, in wrong turns (i.e., long routes to the food box), and in excess distance. Figures 2 and 3 show this graphically. That this change is significant is shown by comparing the critical ratios for the three
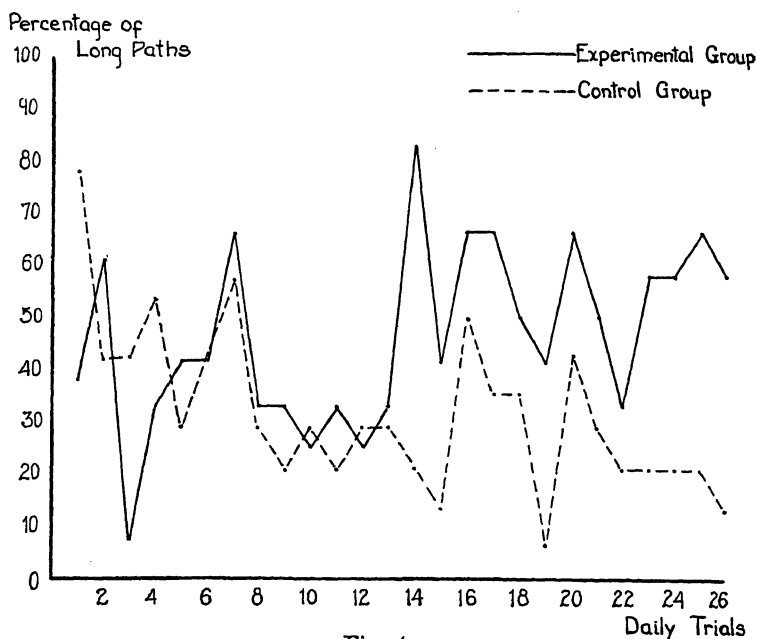
Fig. 4

days preceding the removal of food with that of the three days following. The pooled scores for the three days preceding the removal of reward show a critical ratio of difference between the experimental and control groups of .161, which indicates that the difference is not significant; and, for the three days following, they show a ratio of 3.20, which indicates that the difference is significant. It is interesting to note that for the three days following removal of reward the excess distance becomes larger

on each succeeding day. Evidently the change is not a temporary one caused by an emotional upset, or by a different food box. Inspection of the scores indicates that the rise is due to the fact that *more rats* are searching the maze for reward, that is, *more rats are reacting to the box now as a non-reward box*. After a drop on the fifteenth day the curve of excess distance rises again to reach its peak, and then begins to decline slowly. This slow drop continues until the twenty-fourth day. Inspection of the individual records indicates that the animals, after displaying "searching activity" for two or three days, run about less in the maze and go into the box more readily.

On the twenty-third day the experimental group was not fed. This was done to test the assumption of the experimenter that the animals were really reacting to the box now as a non-reward box. It was held that by adding a twenty-four-hour period without food the rats would be more hungry, and if they were reacting to the box now as a non-reward box they would enter it less and run about more in the maze, and so would show more excess distance. If, on the other hand, there were a "normal trapping time," i.e., if, after some running about in the maze they were to go into the food box and be trapped and if they were not reacting to the box as a specific non-reward object, there would be no reason to expect any change in the score. After the added time without food the excess distance score did jump to a new level of 22.5 units per rat, and the time score showed a corresponding increase of 286.6 seconds per rat. This supports the assumption that the rats were reacting specifically to the box as a non-reward box. On the twenty-fifth day, as an added variation, the rats received a double portion of food; and they had not entirely consumed this when put into the maze on the twenty-sixth day. This was done in order to add a third degree of hunger, approximately zero, to the two degrees already investigated, "hungry" and "doubly-hungry." The excess distance score showed no significant change, but the time score jumped to a new level, an average of 400.58 seconds per rat. This is in agreement with the work of Szymanski summarized above.

When the curves are analyzed it seems possible to say that from the animal's point of view there are at least three "problems" involved. The first, from days 1 to 11, is that of learning the maze, with food at the end; the second, from approximately days 11 to 16, is that of learning to react to the box as a non-reward box; and the third is that of learning to react to the whole maze as a non-reward maze. The second "problem" is learned much more rapidly than the other two. By modification of the animal's hunger state we get varying reactions to the second "problem."

SUMMARY AND CONCLUSIONS

1. When the reward was removed after a training period in a square maze, there was a significant increase in distance run and in time.

2. After continued running of the maze without receiving food, deprivation of food for forty-two hours instead of the usual eighteen caused a large increase in excess distance and in time.

3. On the basis of these results it is suggested that the rats had learned to react to the box as possessing the specific character "non-reward."

4. These results and those of Blodgett and of Elliott give evidence that time and errors, which are the usual criteria of "learning," are seriously affected by reward and hunger conditions.

TABLE 1

Day	Average excess distance per rat		Average time in seconds per rat		Percentage of rats taking long paths	
	Group one (experimental)	Group two (control)	Group one (experimental)	Group two (control)	Group one (experimental)	Group two (control)
1	4.30	9.35	93.13	167.84	.385	.787
2	5.53	4.78	49.27	43.73	.615	.429
3	4.38	3.0	29.24	21.34	.075	.429
4	3.33	6.07	35.41	39.10	.333	.535
5	4.33	2.85	36.91	15.0	.416	.29
6	2.0	3.57	20.58	27.0	.416	.429
7	3.33	4.0	19.5	33.77	.666	.571
8	2.66	2.57	20.04	45.04	.333	.29
9	1.58	1.0	9.06	22.51	.333	.213
10	2.0	1.57	15.73	13.55	.25	.29
11	2.66	.85	14.85	9.91	.333	.213
12	5.91	1.14	48.48	9.31	.25	.29
13	14.91	1.42	231.0	7.07	.333	.29
14	17.16	.85	225.25	7.42	.834	.213
15	9.91	.57	69.54	4.55	.416	.138
16	18.91	2.92	216.96	9.77	.666	.50
17	12.34	1.42	114.48	10.88	.666	.355
18	8.41	1.14	186.16	7.31	.50	.355
19	10.75	.28	90.93	3.95	.416	.066
20	9.41	1.85	108.9	7.48	.666	.429
21	8.91	1.42	117.13	5.31	.50	.29
22	5.33	1.57	63.03	7.12	.333	.213
23	7.66	.85	104.73	5.41	.584	.213
24	22.5	.85	286.6	4.51	.584	.213
25	10.91	.85	206.16	4.8	.666	.213
26	9.66	.78	400.58	6.72	.584	.138

LITERATURE CITED

BLODGETT, H. C.
   1929. ''The Effect of the Introduction of Reward upon the Maze Performance of Rats.'' *Univ. Calif. Publ. Psychol.*, 4:113–134.

ELLIOTT, M. H.
   1928. ''The Effect of Change of Reward on the Maze Performance of Rats.'' *Univ. Calif. Publ. Psychol.*, 4:19–30.
   1929a. ''The Effect of Appropriateness of Reward and of Complex Incentives on Maze Performance.'' *Univ. Calif. Publ. Psychol.*, 4:91–98.
   1929b. ''The Effect of Change of 'Drive' on Maze Performance.'' *Univ. Calif. Publ. Psychol.*, 4:185–188.

GRINDLEY, G. C.
   1929. ''Experiments on the Influence of the Amount of Reward on Learning in Young Chickens.'' *British Jour. Psychol., General Section*, 20:173–180.

HAMILTON, E. L.
   1929. ''The Effect of Delayed Incentive on the Hunger Drive in the White Rat.'' *Gen. Psychol. Mon.*, 5: No. 2.

SHARP, W. L.
   1929. ''Disintegrative Effects of Continuous Running and Removal of the Food Incentive upon a Maze Habit of Albino Rats.'' *Jour. Comp. Psychol.*, 9:405–423.

SIMMONS, R.
   1924. ''The Relative Effectiveness of Certain Incentives in Animal Learning.'' *Comp. Psychol. Mon.*, 2: No. 7.

SZYMANSKI, J. S.
   1918. ''Ein experimenteller Beitrag zur Analyse der bei Entstehung neuer Gewohnheiten mitwirkenden Faktoren.'' *Pflüger's Arch. f. d. ges. Physiol.*, 170:197–220.

TOLMAN, E. C., HONZIK, C. H., and ROBINSON, E. W.
   1930. ''The Effect of Degrees of Hunger upon the Order of Elimination of Long and Short Blinds.'' *Univ. Calif. Publ. Psychol.*, 4: 189–202, 6 figs. in text.

WASHBURN, M. F.
   1926. ''Hunger and Speed of Running as Factors in Maze Learning in Mice.'' *Jour. Comp. Psychol.*, 6:151–188.

WILLIAMS, K. A.
   1929. ''The Reward Value of a Conditioned Stimulus.'' *Univ. Calif. Publ. Psychol.*, 4:31–55.

"INSIGHT" IN RATS

BY

E. C. TOLMAN AND C. H. HONZIK

PSYCHOLOGY.—George M. Stratton, Warner Brown, and Edward C. Tolman, Editors.

Price per volume, $3.50.

"INSIGHT" IN RATS[1]

BY

E. C. TOLMAN AND C. H. HONZIK

INTRODUCTION

Using a maze suggested by the senior writer, H. H. Hsiao[4] conducted an experiment designed to show whether or not rats were capable of grasping "a material, inner relation of two things to each other." More specifically, Hsiao's object was to discover whether a rat can get the "insight" that two paths have a common section—that, if the common section is closed, both of these paths are useless and that only a third, alternative, path not including this common section remains as the proper one whereby to reach the goal. Hsiao obtained what seemed to be positive results, but since these were based on only three rats, it was thought desirable to repeat the experiment with a larger number of animals.

EXPERIMENT I (MAZE I)

Apparatus and method.—The maze used in the first experiment is shown in figure 1. In principle and in general shape it is essentially the same as that used by Hsiao. It presents three paths to food, numbered 1, 2, and 3 in order of increasing length. Further, paths 1 and 2 have a common final section which is not common to path 3. The principal difference between the present maze and Hsiao's is that the final common section is now longer.

---

[1] The cost of this investigation was met in large part by grants to the Department of Psychology from the Research Board of the University of California.

The maze was constructed of unpainted redwood. The alleys were 4 inches wide, the walls 6 inches high. The tops of the alleys were covered with ½-inch mesh hardware cloth. The five gates indicated in the figure were also made of the same hardware cloth. These gates were pivoted at the bottom and slanted upward away from the rat. The upper edges of the gates were held by rubber bands against the covers of the alleys. The tension of the rubber bands was such that the rat by stepping on a
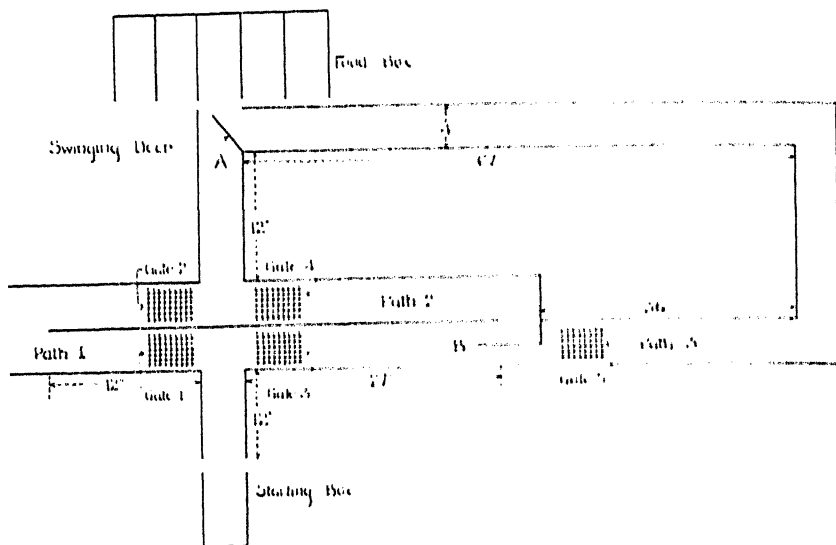
Fig. 1. Maze used in Experiment 1

gate would, by the force of his weight, be able to push the gate down and pass over it. Once over, the gate would swing up behind him and retracing was prevented."

The entrance to each path could be closed by a sliding door, made of beaver board.

General procedure.—The general course of the experiment can be divided into two periods: (1) a *preliminary training period* so as to acquaint the rat with the features of the maze and

---

2 For a more detailed description of this type of gate, see Tolman, Tryon, and Jeffress.(7)

develop a strong preference for Path 1, a somewhat less strong preference for Path 2, and a weak, or no preference for Path 3;[3] and (2) a *final test period* in which to discover whether, when the swinging door at the end of the common section to paths 1 and 2 is locked, the rats, upon retracing out of Path 1, will then have the "insight" to avoid Path 2 and take Path 3 directly— and this in spite of the fact that, in the preliminary training, when the first gate to Path 1 was locked, the rats were in the habit of going directly by way of Path 2 and avoiding Path 3.

For each run, whether in the preliminary training period or in the final test period, the rat was given about 2 grams of a modified Steenbock mash. After the last run for the day the remainder of the daily ration was given in the rat's living cage.

The experiment was carried out with two groups of rats, Group A and Group B, the special conditions and results of which will be presented separately and in more detail below.

GROUP A

Animals.—Group A consisted of 10 male rats of a mixed breed obtained from the Department of Anatomy of the University of California. Nine of the rats were white, one hooded. They were from three to four months old at the beginning of the experiment. None of them had had previous training of any sort.

Preliminary training.—The preliminary training consisted of 6 runs each day for 15 days, making a total of 90 runs for each rat. The first three runs each day were "forced runs," i.e., by blocking successive pairs of the three paths the rat was forced down each of the three paths once. The remaining three of the six daily runs were "free," i.e., by leaving all the paths open the rat could choose a path according to his preference.[4]

---

[3] Many previous experiments have established that, when given an alternative between a long and a short path to food, a rat will come to choose consistently the shorter path: DeCamp[2]; Kuo[5]; Yoshioka[10]; Blodgett[1]; Hsaio.[4]

[4] For the invention of this method of "forced," followed by "free," runs we are indebted to Yoshioka.[9]

The results of the preliminary training were as follows:

Forced runs: These were distributed equally, by virtue of the method, into the three paths, 150 runs in each path.

Free runs: Path 1—309
Path 2— 81
Path 3— 60

When the rats had a free choice, it was evident that by far the greatest preference was for Path 1. The preference for Path 2 as against Path 3 was not great, and is roughly measured by the proportion 81 to 60.

Test period.—Six "insight" or test runs were given on the sixteenth day. The two gates in Path 1 were let down, permitting return. Each rat, as would be expected from the training series, immediately took Path 1. Finding himself blocked at *A* (see fig. 1), he was forced to return to the starting point (the second gate in Path 2 was not let down and this prevented his return by way of Path 2). He was then free to take either Path 2 or Path 3.

Test results.—On the *first* "insight" run, 4 of the 10 rats after returning out of Path 1 avoided Path 2. On the *second* "insight" run, 3 of the 10 rats after returning out of Path 1 avoided Path 2. On the *third* "insight" run, 6 of the 10 rats after returning out of Path 1 avoided Path 2. On the remaining three runs all the rats had learned not to take Path 1, but ran immediately into Path 3, or else in a few cases ran first into Path 2 and then into Path 3.

Since only 4 of the 10 rats avoided Path 2 on the first "insight" run, it was obvious that the results from this group were negative, particularly when we consider that not all these 4 rats avoided Path 2 on their second test run.

GROUP B

Animals.—Group B consisted of 11 male rats, also of varying color, three to four months of age, and without previous training of any sort.

Preliminary training.—The preliminary training consisted of 6 runs a day for 14 days. The first three runs each day, as in Group A, were "forced," that is, one in each path. The next three runs were "free." In the last three of the nine daily runs the entrance to Path 1 was closed by the sliding door at its entrance, so that the rats had to choose directly between Path 2 and 3.

The results of the preliminary training were as follows:

"Free" runs (second three): Path 1—204
Path 2—211
Path 3— 47

Last three runs (choice between paths 2 and 3):

Path 2—343
Path 3— 68

The preference for Path 2 as against Path 3 is quite evident in both types of runs, the "free" and those where choice was restricted to Path 2 or 3.

Test period.—The "insight" runs were given on the fifteenth day. As in Group A the two gates in Path 1 were let down to permit return. To prevent the rat from taking Path 3 or 2 immediately without going first into Path 1, the entrance to Path 2 was closed and not opened until the rat had entered Path 1 as far as the block at A.

The results of the test runs were as follows:

"Insight" run	No. of the 11 rats that avoided Path 2
1	1
2	1
3	2
4	6
5	7
6	9
7	9

The results are again negative.

The fact that all but 2 of the 11 rats avoided Path 2 on the sixth and seventh runs does not indicate "insight" in the sense

in which we wish to use the term. For it appears obvious that, after having several times found themselves blocked by taking Path 2, the rats would *learn* to avoid this path. Their subsequent avoiding of Path 2 is, then, mere evidence of "trial and error" learning and does not indicate any grasp of the fact of the common section to paths 1 and 2 previous to their first experience of the block in Path 2.

EXPERIMENT II (MAZE II)

Apparatus and conditions.—In view of the negative results obtained on Maze I it was decided to try a maze in which the choice between paths 2 and 3 would require a larger movement, that is, a turning through 90° to the right or left (fig. 2).

A group of 11 male rats, also of mixed breed and without previous maze training, was run in this maze.

Preliminary training.—The preliminary training consisted of 10 runs a day for 13 days. For the first two days the first three of the ten daily runs were "forced," as explained above; the remaining seven runs were "free." By the end of the second day's running all the rats had begun to show a decided preference for the shortest path, viz., Path 1. Therefore, after the second day, only two runs daily (and these not in immediate succession) were permitted over Path 1; in the remaining eight of the ten runs Path 1 was closed by a wire netting set 9 inches back from the entrance, the wire gate at this entrance being let down by removing the rubber band. Thus the rat, entering Path 1 according to his first preference, found himself blocked, had to turn and retrace, and then to choose Path 2 or 3. This sort of retracing from Path 1 had the advantage of being similar to the "insight" run itself in which, however, the retracing is from the block at *A*. Thus both in the preliminary training runs and in the test runs the rat retraces out of Path 1, but, although in the training runs the rat has learned then to take Path 2, in the test run he must take Path 3 in order to show "insight."

It is not meant to imply that the rats invariably entered Path 1 when the wire-netting block was in place. On the contrary they learned to look into the alley without entering and to choose Path 2 or 3 immediately. This propensity, however, was somewhat counteracted by the two runs daily into Path 1, which had the effect of keeping the rat familiar with this path and inducing him to try it frequently.

Fig. 2. Maze used in Experiment II.

Results of training period.—There was a total of 901 runs with Path 1 blocked as described above. Of these runs, 752 were made by way of Path 2 and 149 by way of Path 3. We find a considerable preference for Path 2 as against Path 3, and it is this preference or habit which must be overcome on the "insight" run, when the block is put at A, if "insight" is to be demonstrated.

Test period and its results.—On the fourteenth day 5 "insight" runs were given. The results of these runs are as follows:

Insight '' run	No. of the 11 rats that avoided Path 2
1	5
2	4
3	8
4	8
5	6

All the 5 rats that avoided Path 2 on the first run blundered into Path 2 on the second run. Of the 6 rats who did not avoid Path 2 on the first run, 4 avoided Path 2 on the second run. No rat avoided Path 2 consistently. It is clear that again ''insight'' cannot be inferred from the results.

EXPERIMENT III (MAZE III)

It now seemed possible to the writers that the situations presented by the two mazes I and II were not simple enough for the animals to show ''insight.'' A third maze was therefore built.

Apparatus and methods.—This maze (fig. 3) was of the elevated type first used by Miles.[6] The rails, or runways, were 1½ inches wide, and 30 inches above the floor. The gate in Path 2 was inserted in a short tunnel and was similar to the gates used in the other mazes. Its purpose was to prevent return by way of Path 2. The blocks used to prevent entrance upon any path were of wire netting mounted upon a strip of wood fitted over the rail.

GROUP A

Animals.—The rats, 15 in number, used in this group on this maze were all males of mixed breed, from five to eight months of age, and had been previously run in an experiment on inheritance[8] for 21 days in a 17 unit T-maze. An interval of six weeks elapsed between that running and the present experiment. It may be well to emphasize that the maze in which the rats had their first training was an automatic self-recording maze[7] of the ordinary T-type, set on the floor, with 5-inch walls and 4-inch alleys, and was thus of an entirely different kind from the elevated one used in the present experiment.

Preliminary training period.—Days 1–8 (twelve runs a day).
By the end of the first day preference for Path 1 was evident, so
that thereafter 10 of the 12 daily runs were with Path 1 blocked
at *A* (see fig. 3). As occurred in the case of Maze II, the rats in
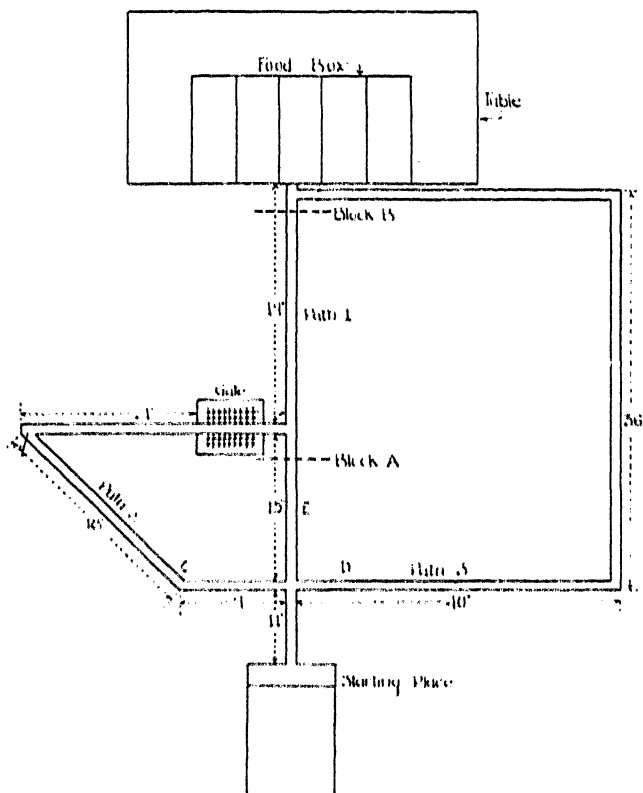
Fig. 3.   Maze used in Experiment III.

this maze also learned merely to look toward block *A* and make
the choice between paths 2 and 3 immediately without entering
Path 1 at all.

Special effort was made to prevent such immediate choices,
for the following reason. In the "insight" or test runs (with
the block at *B*) the rat is forced to turn and head back toward

the starting point; the behavior of the rat on Path 1 in the training runs should be similar to his behavior in the "insight" runs in this respect, that the rat, in the training runs, should make his choice of Path 2 or Path 3 while headed back toward the starting point. In this way the training runs are made to differ from the "insight" runs only in the position of the blocks. In the training runs the block is at *A*, in the test runs it is at *B*. The choice between paths 2 and 3 is made, therefore, in both training and test runs after the rat has been stopped and has been turned back, but the choice in the test run must be different from that of the training run if it is to show "insight." In order to induce the rats to attempt Path 1, at least two runs each day were given over Path 1, with no block at *A*. Knowing that he had made a successful run over Path 1 recently the rat was more likely to try it again. But this was not entirely successful. Consequently, still another method was tried. For the wire-netting block at *A*, one made of a piece of clear window glass was substituted on the fourth day. This was considerably less visible than the wire block. This method was effective for a time, but again the rats learned to see the glass and not to approach it. As a last resort, rats that did not approach the block at *A* voluntarily were forced to do so by blocks placed at *C* and *D*. Finding paths 2 and 3 blocked the rat ran to block *A*. The blocks at *C* and *D* were then quickly and quietly removed while he was still facing toward block *A*, and on his return he chose either Path 2 or Path 3.

Days 9–13 (twelve runs a day). On the ninth day of the training period a new type of run was introduced. This consisted of moving the block *A* on Path 1 forward from the point *A* to the point *E*, and setting up also block *B*. With this arrangement the rats ran to the block at *E*, had to retrace and then choose Path 2 or Path 3. If Path 2 was chosen the rat found himself blocked again at *B*. To permit him to return to the starting point again the block at *E* was quietly removed while he was facing block *B*. Having returned now to the starting point

the rat could then take Path 3 or blunder into Path 2 by way of which he had just found himself blocked. It is interesting to note that the first time this type of run was given all the 15 rats chose Path 3 on the second return to the starting point; and thereafter very few mistakes of taking Path 2 a second time were made.

The defect inherent in this sort of run is obvious; it is very much like the "insight" run which was to follow later and may be considered direct training for that later run. It is therefore important to emphasize that each rat had only 12 runs of this sort, that these runs were distributed over 5 days (average of 2 a day), and that the runs were interspersed among 65 other runs which each rat had during these 5 days. The fact that the runs were few in number and were scattered among other runs led the experimenter to believe that their training effect could not be great. Further, it should be noted that block B, on this run, is encountered not by way of Path 1 (as in the "insight" run) but by way of Path 2.[5]

The advantage of this run and the only reason for its introduction is this: If the rat had never before encountered the block at B, his first encounter with it in the test or "insight" run might conceivably cause considerable confusion, a factor we wished to minimize.   Therefore, some acquaintance with block B was thought advisable, not by way of Path 1 but by way of Path 2, as just said.

Results of training period.—There was a total in all 13 days of training of 1357 runs with block A in place. We ask now how many times was Path 2 chosen and how many times Path 3, since this will tell us how strong a preference there was, or how strong a habit was formed, for Path 2. Of the 1357 runs 1229 (90.57 per cent) were by way of Path 2, 128 runs (9.43 per cent) by way of Path 3. The preference for Path 2 could hardly be much stronger, especially when we consider that more than half of the

---

[5] A later control group (see below, Group B) without the introduction of this special run gave exactly the same sort of results as did the present group.

runs over Path 3 were made in the early part of the training while the animals were incompletely familiar with the maze. There were also 171 "forced" runs over Path 3, paths 1 and 2 being blocked.

The number of times each rat took paths 2 and 3, when the block was at *A*, is given in table 1.

TABLE 1

Path \ Rat	H58	H65	W56	W53	W59	H64	W74	W50	W60	B51	H53	W22	W29	W55	W16	Total
2	84	83	87	78	73	78	84	80	86	81	73	73	88	84	82	1214
3	5	6	10	8	13	8	3	3	3	14	27	15	1	6	6	128

Test period.—The "insight" runs were given on the fourteenth day. The results are as follows:

"Insight" run	No. of the 15 rats that avoided Path 2
1	14
2	13
3	10
4	12
5	11
6	12
7	13

The first "insight" run must be considered crucial since after this first run the element of training enters. And for the first "insight" trial, 14 of the 15 rats responded correctly, taking Path 3 immediately in spite of the strong preference and habit for Path 2.

Taking the number of errors made by individual rats during the seven test runs, the results are as follows:

In 7 runs: 1 rat made 5 errors
           3 rats made 4 errors
           3 rats made 1 error
           8 rats made 0 errors

More than half the rats made 7 perfect runs. Only one rat made an error on the first test run. The others made errors on later runs, notably the third. The fact that 6 rats chose the right path, viz., Path 3, on the first test run and made errors on later runs may be explained by a temporary reassertion of, or lapse into, an old habit.

If the taking of Path 2 or Path 3, after return from block *B*, were a matter of pure chance similar to the tossing of a coin, the probability[a] of 14 out of 15 rats taking paths 3 and 1 rat taking Path 2 would be .00046. The actual result of 14 rats taking Path 3 and 1 rat taking Path 2 on the first test run indicates, therefore, a very decided "loading" in favor of Path 3, in spite of the fact that the "loading" during the training period was just the reverse, viz., in favor of Path 2.

Retraining and alternated runs.—On the day following the test runs, viz., the fifteenth, the ordinary training runs were resumed, 10 of the 12 runs on this day·being with the block at *A*. On the sixteenth day 11 runs were given, and these were as follows: The first four runs were "insight" or test runs, the next two were training runs with block at *A*, then four more "insight" runs, and finally one more training run. Thus, for the entire group of 15 rats there was a total of 120 "insight" runs, and a total of 45 training runs on this day. For the training runs with block at *A* the taking of Path 3 was called an error, since Path 2 was open and was the shorter path. In the "insight" runs the taking of Path 2 was as usual called an error. The errors were as follows:

> In the 120 "insight" runs—18 errors
> In the 45 training runs—4 errors

In the "insight" runs we may say that each rat made an average of one error in 8 runs, while in the training runs each rat made an average of one-fourth of an error in 3 runs.

This remarkable ability to adjust correctly to changing conditions suggested the idea of alternating the blocks between *A*

<hr/>

[a] This has been calculated by the point binomial: see Holzinger.[3]

and *B* on successive runs, i.e., one training run with block at *A*, the next an ''insight''. run with block at *B*, the third a training with block at *A*, and so on. This was tried on the seventeenth day. Eleven runs were given, 6 being training runs and 5 test runs. Counting errors as above, the results were as follows:

	"Insight" errors	Training-run errors
10 rats	0	0
1 rat	2	1
1 rat	0	2
1 rat	1	0
1 rat	3	0
1 rat	1	0

In these alternated runs both the glass and the wire-netting blocks were used, and their positions were alternated between points *A* and *B*. For one run the glass block was at *B*, the wire block at *A*, and for the succeeding run the glass block was put at *A*, the wire block at *B*. This was to check the possibility that the rats might have become conditioned to the nature of the blocks, the glass block being a sign for Path 2, the wire block for Path 3. The alternation of blocks caused no change or confusion in the behavior of the rats. Their behavior gave unmistakable evidence that they had grasped so well the relation of the paths to each other that they were able to take the right path wherever either block was placed.

GROUP B

To ascertain the possible effect of the twelve special runs per rat which were introduced during Days 9–13 with Group A, viz., the runs with blocks at *E* and *B*, which might perhaps have been direct training for the ''insight'' trials, another group of 10 male rats of mixed breed from five to eight months of age and without previous training of any sort was given training for 14 days, but without these blocks-at-*E*-and-*B* runs. Otherwise the general conditions were the same as for Group A.

Results of training period.—There were for the entire group of 10 rats 1178 runs with Path 1 blocked at *A*. Of these 1178 runs, 1081 (or 91.77%) were over Path 2, and 97 (8.23%) over

Path 3. The preference for Path 2 as against Path 3 is obvious and is even stronger in this group than in the previous Group A.

The number of times each rat took paths 2 and 3, with the block at *A*, is given in table 2.

TABLE 2

Rat / Path	H82	W11	H52	W51	H5	H55	W65	W31	W17	H1	Total
2	107	104	106	108	108	109	110	107	111	111	1081
3	8	17	13	5	15	6	1	20	4	8	97

Results of test period.—Day 15. The results of the "insight" runs were as follows:

"Insight" run	No. of the 10 rats that avoided Path 2
1	7
2	9
3	all
4	8
5	all
6	9
7	9

Taking the number of errors made by individual rats during the seven test runs, the results were as follows:

In 7 runs: 1 rat made 3 errors
1 rat made 2 errors
3 rats made 1 error
5 rats made 0 errors

The probability of 7 out of 10 rats taking Path 3, and 3 rats taking Path 2, assuming that the choice of these paths is a matter of pure chance, would be 0.117. That is, assuming pure chance, we should expect a distribution of this sort about twelve times in one hundred. But actually there was a heavy "loading" the other way, viz., in favor of Path 2, built up during the training runs, as is indicated by the proportion of 1081 runs in Path 2 to 97 runs in Path 3.

RESULTS

1. "Insight," in the sense in which we have used the term here, seems to be definitely proved for Maze III with both Group A and Group B. That is, under the conditions of this elevated maze and of the kinds and amounts of preliminary training given, the rats of both groups, upon *first* finding a block in the final common path, as a result of taking one "entering" path (Path 1) *immediately* (i.e., without any trial and error learning) also avoided the taking of the other "entering" path (Path 2). And this result was obtained in spite of the fact that these rats had shown a very strong propensity to take this second "entering" path, when the first "entering" path (and not the final common path) was blocked.

2. No evidence of such "insight" was obtained under our conditions for either Maze I or Maze II.

DISCUSSION

To explain the fact that we obtained no evidence of insight with our Maze I, although Hsaio[4] did obtain evidence of such insight with a very similar maze, two points are to be noted (1) Our maze was not exactly identical in shape with Hsaio's and (2) we did not give the amount and distribution of preliminary training that he did. Either of these two points may have been enough to explain the difference between his results and ours. For the factors which actually govern the appearance or non-appearance of "insight" are in the present state of our knowledge still quite uncertain.

To explain the fact that no insight was obtained in Maze II although it was obtained in Maze III which had an identical ground pattern, it would seem important that Maze III had no side walls as did Maze II and hence the rats were able in Maze III

to "see" the situation as a whole. Or, even if the rats in Maze III were not able to "see" all the paths at any one moment, they might still have been better able to grasp the connections between the paths, owing perhaps to the open space on all sides of the runways, which may have served to accentuate the relations between the paths.

LITERATURE CITED

[1] BLODGETT, H. C.

    1929. The effect of introduction of reward upon the maze performance of rats. *Univ. Calif. Publ. Psychol.*, 4:113–134.

[2] DeCAMP, J. E.

    1920. Relative distance as a factor in the white rat's selection of a path. *Psychobiol.*, 2:245–253.

[3] HOLZINGER, K. J.

    Statistical methods for students in Education. (Boston, Ginn & Co., 1928), chap. 11.

[4] HSIAO, H. H.

    1929. Experimental study of the rat's insight within a spatial complex. *Univ. Calif. Publ. Psychol.*, 4:57–70.

[5] KUO, Z. Y.

    1922. The nature of unsuccessful acts and their order of elimination. *Jour. Comp. Psychol.*, 2:1–27.

[6] MILES, W. R.

    1927. The narrow-path elevated maze. *Proc. Soc. Exp. Biol. and Med.*, 24:454–456.

[7] TOLMAN, E. C., TRYON, R. C., and JEFFRESS, L. A.

    1929. A self-recording maze with an automatic delivery table. *Univ. Calif. Publ. Psychol.*, 4:99–112.

[8] TRYON, R. C.

    1929. The genetics of learning ability in rats. *Univ. Calif. Publ. Psychol.*, 4:71–89.

[9] YOSHIOKA, J. G.

    1928. Preliminary study of discrimination of maze patterns by the rat. *Univ. Calif. Publ. Psychol.*, 4:1–18.

[10] YOSHIOKA, J. G.

    1929. Weber's Law in the discrimination of maze distance by the white rat. *Univ. Calif. Publ. Psychol.*, 4:155–184.

VISUAL DISTANCE PERCEPTION IN THE RAT[1]

BY

ESTHER W. ROBINSON AND E. G. WEVER

This study is concerned with the ability of the rat to use vision in the maze situation. A simple T-type of maze was used under conditions that made it possble to determine at what distances rats are able to ascertain visually whether a path is open or closed. Further, after a measure of the visual capacities of the animals had been obtained under normal illumination, the illumination was gradually reduced in order to determine the animal's capacities under these latter conditions also. Incidentally, since two types of rats were used, albino and pied, the experiment gives some information on the difference in visual capacities of pigmented and unpigmented animals.

EXPERIMENTAL PROCEDURE

Fifteen rats were used, all males, about two months old. Seven of these were albinos, six pere pied, with hoods, and two were uniform gray, one very dark and the other somewhat lighter; the pied and gray animals all had pigmented eyes, and for the purposes of this experiment may be classed together.

Preliminary to the main experiment the animals were trained on a 14-blind T-type maze[2] in complete darkness in order to

---

[1] This experiment was performed in the Psychological Laboratory of the University of California in 1927; publication has been unfortunately delayed.

[2] This maze was one devised by M. H. Elliott and kindly loaned for our use; for its description and illustration, see Elliott, "The effect of change of reward on the maze performance of rats," *Univ. Calif. Publ. Psychol.* (1928), 4:20-21. The curtains, as described by Elliott, had not been added at the time of our use of the maze.

obtain an index of the activity and learning ability of the animals apart from the visual factor. To make it possible to follow the rats in the maze during this training, they were provided with tape collars bearing a daub of luminous paint. After a preliminary run the first day, the animals were given three runs daily for from nine to twelve days, which in most cases was adequate for mastery of the task.

In the main experiment a simple unpainted redwood maze of T-form was used, as illustrated in figure 1. Two paths, *R* and *L*, led from the entrance to the food, but doors of the vertical sliding type, and of the same material and color as the walls of the maze, were provided at *d, d* to permit the closing of either path, as desired. Along the top of the paths a row of electric lights gave even illumination. At the choice point, *P*, the right and left alleys were obscured from view by two black flannel curtains, *c, c*, making it necessary for the rat to enter the blind in order to see whether the path was open.

For about every third trial both paths were left open and the rat made his way unimpeded to the food. For the remaining trials both doors were closed until the rat had passed into one alley, had turned around and started back; then the door of the unentered alley was quietly opened by means of a cord in the hands of the experimenter and the animal thus permitted to pass along that way. Each alley was marked off at 3 inch intervals so that the distance from the door at which the animal turned back could be recorded.

Each animal was given ten trials daily in this situation. There were three trials with both doors open, and seven in which the animal was obstructed by a door and forced to retrace his path. The animals showed for the most part a ready ability for their task. As one would expect, they at first went the whole length of the alley and spent a good deal of time in exploration, but soon such activity largely disappeared, and the behavior was reduced to very simple terms: the animal, often after preliminary hesitation at the choice point, ran under one curtain and

into its alley for a little distance, then brought himself up
abruptly, perhaps skidding a bit in the stopping process, turned,
and passed through the other path with no further delay or uncer-
tainty. The distance from the closed door at which the turning
was made increased gradually during the first few days' train-
ing, and reached its maximum in most cases after about 20 days.
Training was continued for 25 to 35 days.
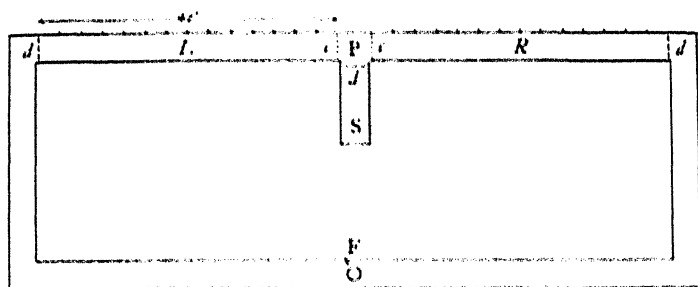
Fig. 1. Diagram of the two way maze. *S*, starting point. *P*, choice
point. *L*, *R*, left and right alleys. *c*, curtain. *d*, door. *F*, food pan.

The reason for the frequent trials with both doors open
obviously was to prevent the formation of a habit of systematic-
ally going down one path a certain distance and then turning
back. That such a habit did not appear is evidenced by the rare
occasions on which the animals turned back when the path was
open; no rat did this more than five times during the training,
and the average was about two times. To guard further against
the mechanization of activity, the rhythm of "turn back twice
and go forward once" was occasionally broken up by forcing the
animal to turn back twice in a given trial before opening the
door. Such variations of the usual procedure seemed to cause
little or no disturbance of the animal's performance.

After training for 25 to 35 days under normal illumination,
an adjustable rheostat was placed in series with the lamps and
the illumination was reduced by small amounts daily until the
animals were running in almost complete darkness. This pro-
cedure took 24 days, the resistance of the rheostat being in-

creasd by a certain amount each day; the number of daily trials were increased to fifteen (five of which were "open" runs). Toward the end of the period the illumination was so low that the rats had to be provided with luminous collars, as in the preliminary experiment, in order to be visible in the maze.

The results of these experiments are given in the form of graphs in figures 2 to 16; the graphs on page 237 are for the seven albino animals, numbered A 1–7, while those on page 238 are for the eight pigmented animals, numbered P 8–13 (pied) and G 14–15 (gray).

In each figure three curves are shown. The first, marked N, shows the performance of the animal under normal illumination; successive days are shown along the abscissa, while distances from the closed door that the animal turned back are shown along the ordinate. The points plotted are averages of seven trials on a given day.

The second curve, marked R and made up of broken lines, shows the performance of the animals as the illumination is reduced a step at a time each day. Each plotted point represents an average of ten trials.

The third curve, on the extreme right, shows the results of the preliminary experiment, when the animals were trained on a 14-blind maze in complete darkness. Days are shown along the abscissa, and number of errors along the ordinate. The points plotted represent the errors of a single trial on a given day.

A consideration of the curves for the preliminary experiment shows that the rats were able to learn the maze with fair readiness. There are apparent differences in the performances of the individual animals, but no significant difference between the albino and the pigmented groups.

Such a difference is immediately obvious, however, when we consider the results of the main experiment. The N-curves for the various animals are of the some general form, showing the steady increase in the distances from the door at which the animals turned back as the training progressed, but the maxi-
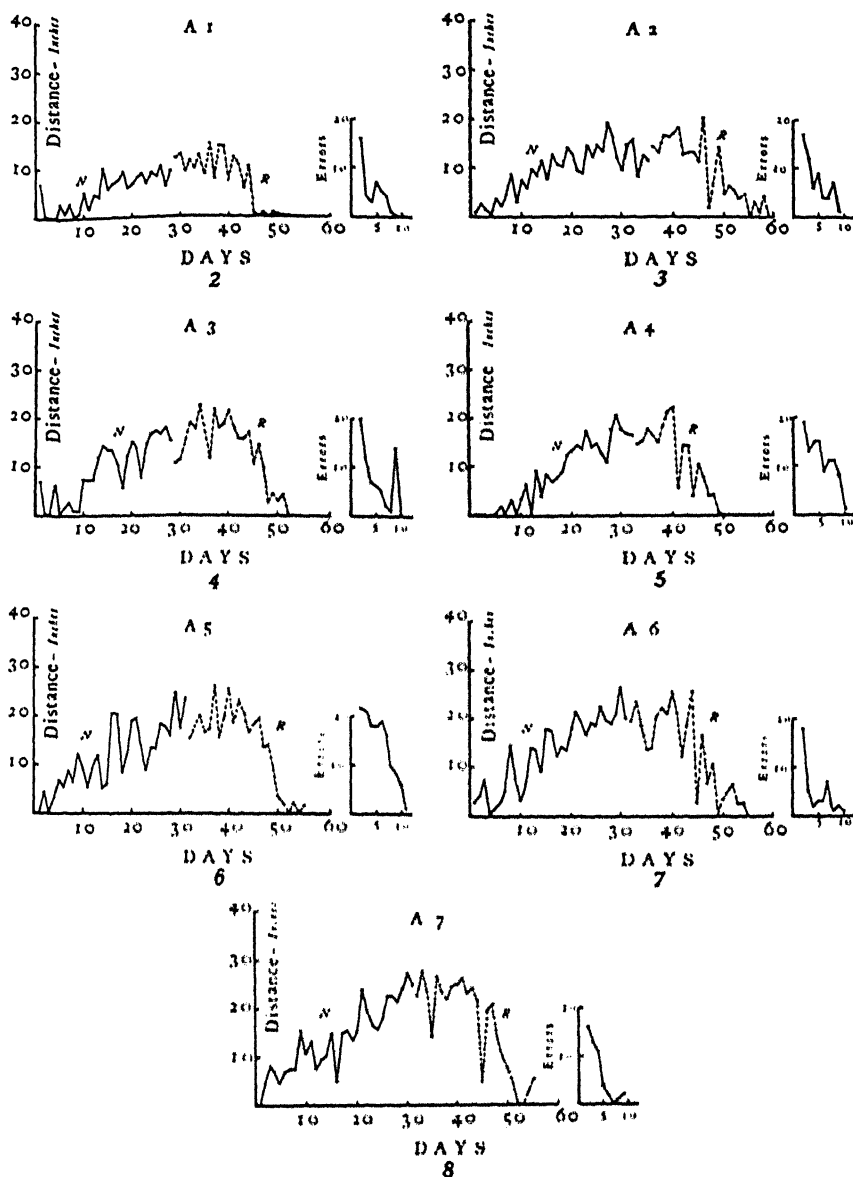
Figs. 2–8.   Performance curves for the albino animals.   In each figure, curve *N* is for normal illumination, and curve *R*, for reduced illumination; main experiment.   Small curve to right in each figure is the error curve in 14-blind maze in the dark.
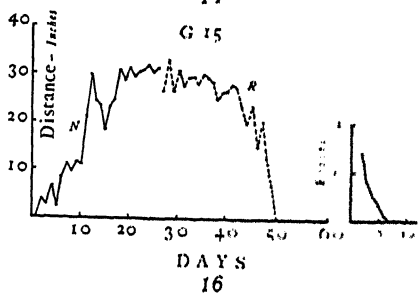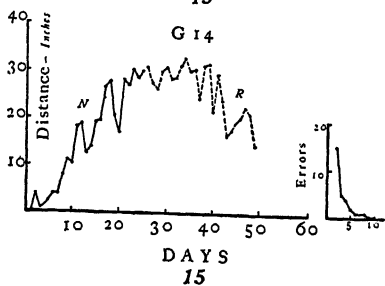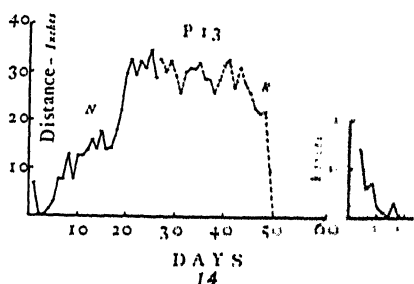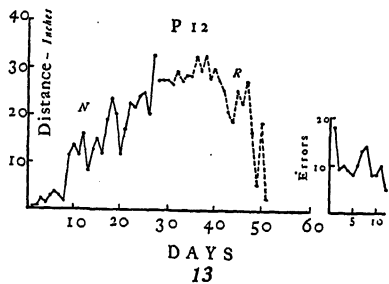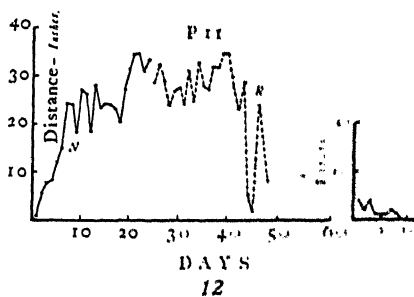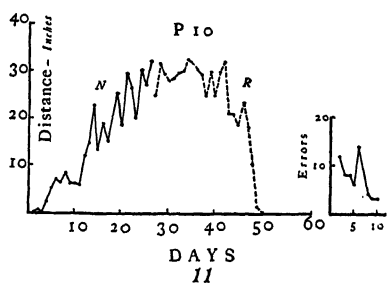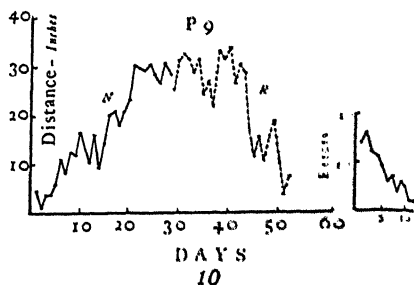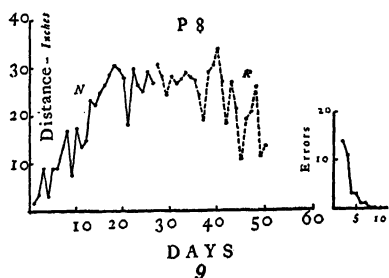
Figs. 9–16. Performance curves for the pigmented animals.

mum levels of the curves are without exception higher for the pigmented animals, showing a greater capacity of distance-vision. The maximum distances for the pigmented animals vary from about 28 to 31 inches, averaging 30 inches, while for the albinos the distances vary from 11 to 24 inches, with an average of 18 inches. The group difference is thus about 12 inches, in favor of the pigmented animals.

The superiority of the pigmented animals was still maintained as the illumination was reduced. The R-curves are in general of a characteristic form: the high level of performance was fairly well maintained as the illumination was reduced, up to a certain point; on further reduction of the illumination, the performance was seriously impaired.

The fact that under favorable conditions rats are able to detect, at distances of 20 to 30 inches, whether a path is open or closed is of obvious relevance for maze work in general. It is plain that the use of simple blinds of this order of magnitude admits their elimination in visual terms as soon as the rat has learned the nature and significance of a blind as such. The use of "elbows" or "dumbbells" at the termination of the blinds will of course rule out the visual factor when it is desirable to do so. A much simpler device suitable for maze work in general is a small cloth curtain, as used above, hung in every alley (blinds and true paths alike) about four inches from the choice point.[3]

SUMMARY

Rats are able to ascertain visually whether a path is opened or closed at distances of about 18 inches for albinos and 30 inches for pigmented animals. The capacity suffers a breakdown as the illumination is greatly reduced, but the pigmented animals remain superior at all stages. The ability shown seems to be largely independent of the general activity and learning capacity of the animals as revealed by maze performances in complete darkness.

[3] For the use of such curtains, see Elliott, *op. cit.*, and other recent experimental studies from this laboratory.

.

DEGREES OF HUNGER, REWARD AND NON-REWARD, AND MAZE LEARNING IN RATS

AND

INTRODUCTION AND REMOVAL OF REWARD, AND MAZE PERFORMANCE IN RATS

BY

E. C. TOLMAN AND C. H. HONZIK

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—Warner Brown and Edward C. Tolman, Editors.

Price per volume, $3.50.

DEGREES OF HUNGER, REWARD AND NON-REWARD, AND MAZE LEARNING IN RATS[1]

BY

E. C. TOLMAN AND C. H. HONZIK

It has been shown by Blodgett,[2] Williams,[10] and Elliott[5] that hungry rats that are non-rewarded in the maze (i.e., given no food, or water instead of food, at the end of each run) show a relatively poor maze performance during such non-reward periods. Somewhat similar results have been obtained by Warden and Haas[9] and by Grindley.[7]

Tolman, Honzik and Robinson[8] found that rats which were abundantly fed after each run and which gained weight during the course of the experiment learned more slowly, i.e., made more errors and took more time in individual runs, than rats which were fed less and that lost slightly in weight during the experiment. Anderson and Smith[1] in a study of the effect of quantitative and qualitative stunting upon maze learning in the white rat showed that "stunted rats are superior to rats that grow normally in relearning a maze."

In general, these two groups of studies indicate that either lack of appropriate reward or lack of motive decreases the rate of overt improvement in maze performance. The purpose of the present experiment was further to investigate all four conditions—reward, non-reward, hunger, and lack of hunger—and to make more accurate comparisons of their effects.

APPARATUS AND METHODS

Maze.—The maze used was a 14-unit T-maze made of unpainted redwood. The arrangement of the blinds is shown in figure 1*a*. The dimensions of one unit, which includes the stem and a cul-de-sac, are given in figure 1*b*. The gates shown in figure 1*b* were placed at the same point in each of the fourteen
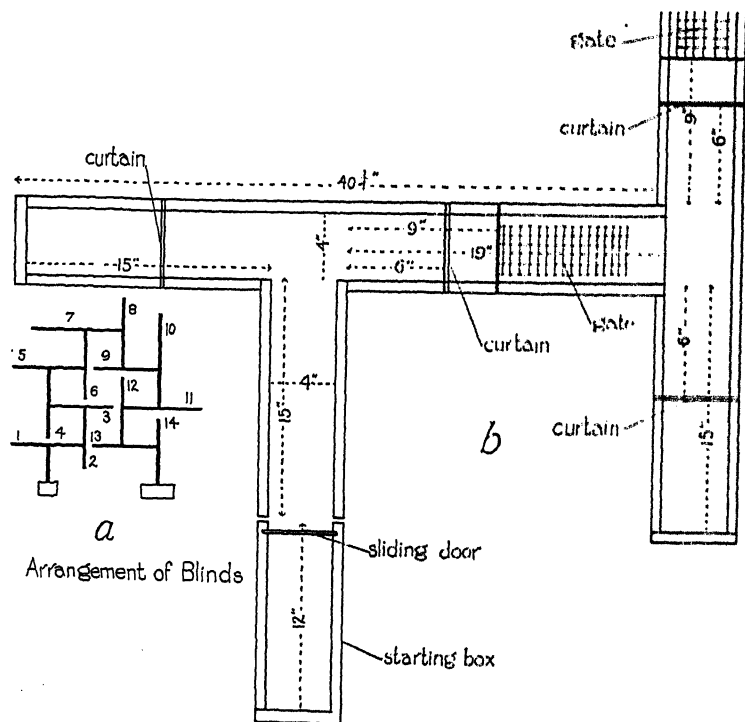
Fig. 1.

units. Their sole purpose was to prevent return of the rat into a unit he had already traversed. Black cloth curtains, placed at the points indicated, prevented the rats seeing any differences between the blind alleys and the true path. The food boxes at the end of the maze contained five compartments, one for each of five successive rats. The entire maze was covered by hardware cloth with a half-inch mesh.

General procedure.—Training for all the four groups of rats was carried out concurrently, under identical conditions, and all groups had the same preliminary training.

Preliminary training.—This accustomed the rats to being handled, and taught them to manipulate the gates and curtains. It consisted of two runs a day for five days, as follows: first day, two runs in a 30-inch "straightaway" with no gate or curtain; second day, two runs with curtain in place but no gate; third day, two runs with both gate and curtain in place; fourth day, two runs in a single T-unit with cul-de-sac to the left and with two gates and three curtains in place; fifth day, same as the fourth day. During the preliminary training the rats were fed at the end of each run, but sparingly, so that, during the five days, each rat lost from 5 to 15 grams.

Training proper.—This consisted, for all the groups, of one run a day in the 14-unit maze for seventeen days. The runs were given each day at as nearly the same hour of the day as possible. Small sections of the four groups were run concurrently; this assured that improvements in technique, if any, would affect all groups equally.

The four groups of rats were differentiated from each other in respect to hunger and reward as follows: the rats of the *hungry rewarded group* (to be designated hereafter as HR Group) were fed their full daily rations of modified Steenbock mash in the food box at the end of the run. Each individual was weighed every third or fourth day during training and his ration was limited, in proportion to his weight, so as to make him lose from 10 to 36 grams. (The amount of absolute loss depended somewhat upon his original weight.) (Table 1.)

The rats of the *hungry non-rewarded group* (HNR Group) were fed *in their living cages,* but not less than three, nor more than four, hours after the daily run. The three-hour interval, it was thought, was long enough to prevent an association being formed between the running of the maze and the food reward.

TABLE 1

INITIAL WEIGHTS AND GAINS AND LOSSES IN WEIGHT IN GRAMS DURING TRAINING

	Hungry reward			Hungry non-reward			Less hungry reward			Less hungry non-reward	
Rat No.	In. Wt.	Loss	Rat No.	In. Wt.	Loss	Rat No.	In. Wt.	Gain	Rat No.	In. Wt.	Gain
W83	110	13	B11	130	15	B8	92	18	W20	120	20
W87	125	10	W79	132	17	B5	116	10	W89	122	18
W72	130	15	W22	140	15	W78	120	12	G2	122	21
W15	140	10	W90	140	16	W20	120	15	B10	123	22
W11	140	15	W70	150	15	W73	122	18	W85	130	26
W23	146	16	W28	158	14	H3	132	20	W40	132	26
W14	150	12	W13	158	15	W48	133	25	W66	140	30
W7	152	18	W19	162	13	W71	135	22	H2	142	29
W82	156	16	W5	162	10	W17	138	23	B1	145	31
W10	156	18	H4	164	12	W3	140	26	W1	148	28
W77	150	14	W60	165	15	W17	140	30	W4	150	40
W54	160	15	W88	168	19	W3	140	32	W2	150	32
W6	162	20	W55	172	17	W16	143	31	W52	160	18
W49	162	11	W47	180	20	W86	145	31	W18	166	28
W67	164	14	W46	180	21	W11	145	33	W27	168	32
W68	165	20	W14	180	20	B2	150	30	W25	170	30
H47	170	28	W91	182	18	W5	153	34	W32	174	31
W29	174	20	W81	184	25	H46	154	32	W69	175	25
W59	175	26	W26	190	22	W9	155	35	B3	178	26
W23	175	20	W56	190	22	W2	158	37	W45	185	28
W53	183	31	W43	192	19	W4	160	40	W57	190	28
W39	184	21	W5	202	24	W1	170	35	W14	190	27
W15	195	25	H45	202	21	W12	172	36	W10	195	25
W65	200	30	W38	210	21	W30	180	38	W15	200	20
H1	200	25	W17	210	17	G1	188	34	W13	205	5
W35	202	23	W76	218	22	W44	190	35	W16	210	8
W12	220	30	W18	220	18	W51	192	27	W12	210	18
W16	228	34	W13	220	24	W36	195	25	W31	212	32
W34	230	30	W20	220	20	W4	202	38	W92	212	26
W22	235	35	W19	230	30	W74	204	28	W6	218	30
H52	238	36	W61	230	28	W75	230	30	H51	252	14
W96	244	35	W7	250	25	W6	234	28	W9	260	28
W64	255	36	W62	255	27	W95	252	15	H1	270	25
W..	...	..	T..	270	31	...	...	...			

The boxes at the end of the maze for these rats were never used for any other rats and care was taken that no food should ever be placed in these "non-reward boxes." The rations for these rats were also limited, in order to make them lose weight to approximately the same degree as the HR rats. (Table 1.)

The *less hungry rewarded* rats (LHR Group) were fed in the end food box, in sufficient amounts to increase their weights (4 to 40 grams) during the seventeen days' training. (Table 1.)

The *less hungry non-rewarded* rats (LHNR Group) were fed in their living cages, like the HNR rats, not less than three, nor more than four, hours after the daily run. In amount their rations equaled approximately those of the LHR rats. They gained approximately the same weight as did the LHR rats. (Table 1.)

The rats.—Each of the four groups consisted of 36 male rats from 3½ to 5 months of age, and of mixed coat-color, some being hooded, some black, but the majority white. The colors were distributed by chance fairly evenly among the groups. All rats at the beginning of their training were healthy and in good physical condition. As against the 144 rats that completed the experiment, there were five that were discarded because of illness and four that for unknown reasons refused to run.

Scoring.—Time and error records were kept. An entrance into a blind the full body-length (not including the tail) was considered an error. No attempt was made to record degrees of entrance. A second or third entrance into a blind during the same run was also considered an error and included in the records. Returns into units just traversed were prevented by the gates; there were therefore no retracing errors.

The blinds in the maze were numbered in order from the first to the fourteenth, and each error was recorded by the number of the blind in which it was made. All movements and errors of the rat were clearly discernible in a convex mirror hung over the maze, and with a little practice were easily recorded.

GROSS QUANTITATIVE RESULTS

Learning curves.—The point of first interest is a comparison of the learning curves based on error scores of the four groups. These are given in figure 2.

The curve for the HR Group, the group in which there were present both a strong internal drive (hunger) and an obvious
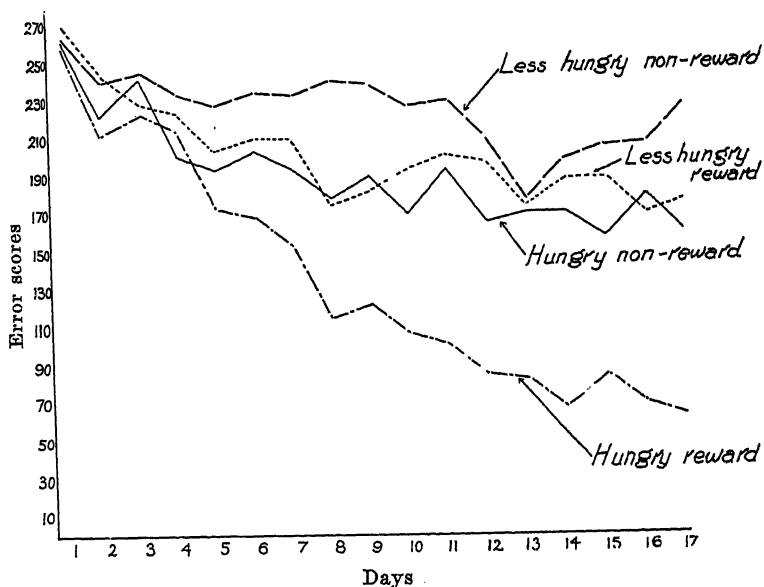
Fig. 2. Error curves for four groups,. 36 rats.

satisfaction of this drive (food), is seen to be a typical learning curve and indicates more rapid learning in this group than in any of the other three. The LHNR Group, in which there were absent both strong drive and any obvious reward, learned more slowly than any of the other groups; however, some learning apparently did take place. This is explained by the assumption that the outlet from the maze is in itself a weak reward, an assumption corroborated by the results for the different blinds (see fig. 6).

The learning curves of the remaining two groups, less hungry rewarded (LHR) and hungry non-rewarded (HNR), are very much alike, indicating that lack of drive with reward, and presence of drive without reward, were factors of about equal potency in the learning of the maze.

Error curves alone, however, do not tell the whole story of the learning process. Time is also an important element. Time curves for the groups are shown in figure 3.
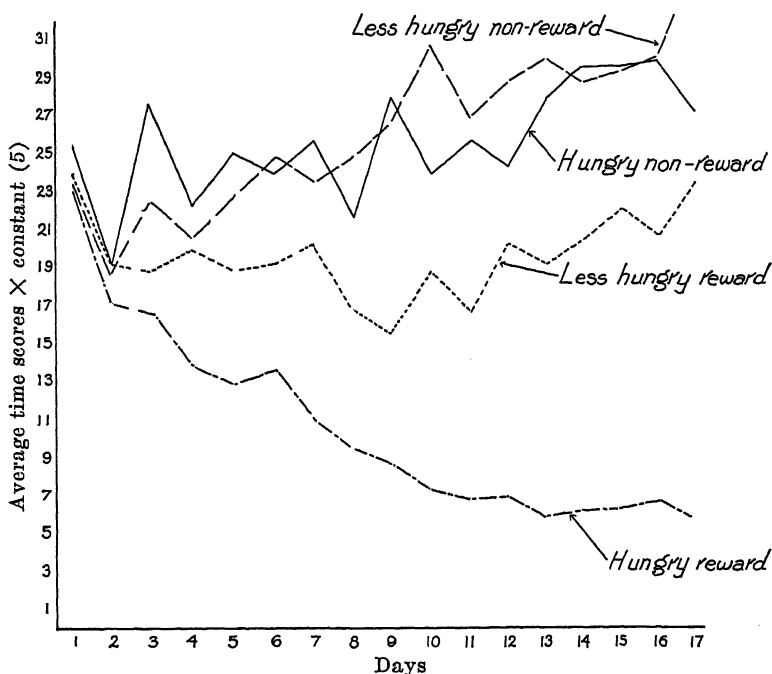
Fig. 3. Time curves for four groups, 36 rats.

Here again the typical learning curve of the HR Group is considerably lower than the other curves. The relations between the time curves of LHNR, LHR, and HNR groups, however, are not quite the same as those between the error curves for these groups. The HNR Group now gives as high a curve as does the LHNR Group.

Two other points of interest appear in the time curves of LHNR, HNR, and LHR groups: (1) the *upward trend of all*

Less hungry non reward
Mean=105.61

Less hungry reward
Mean=94.52

Hungry non-reward
Mean=89.72

Hungry reward
Mean=69.00
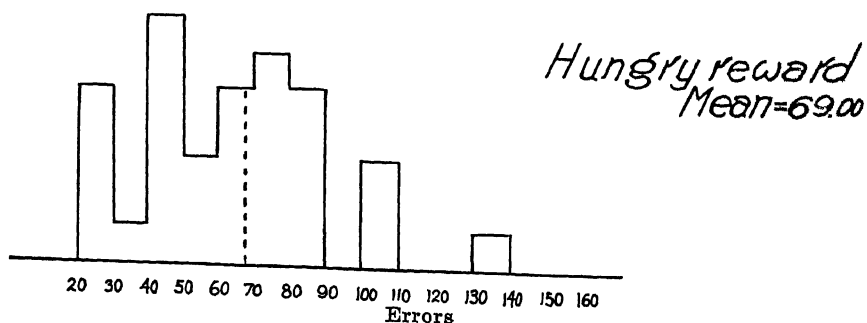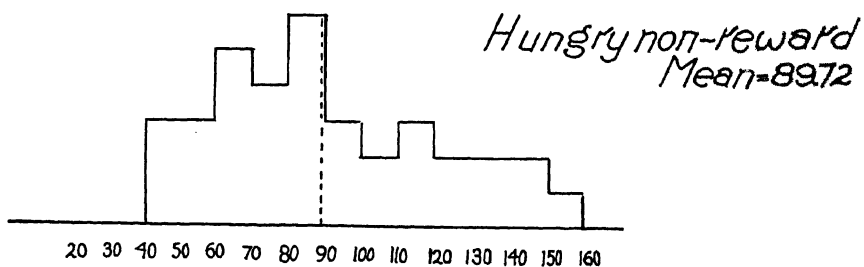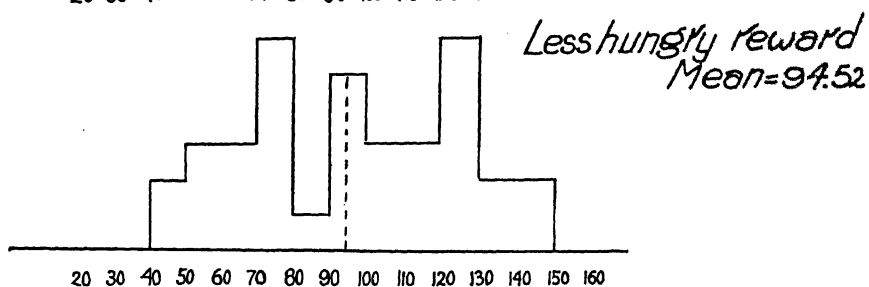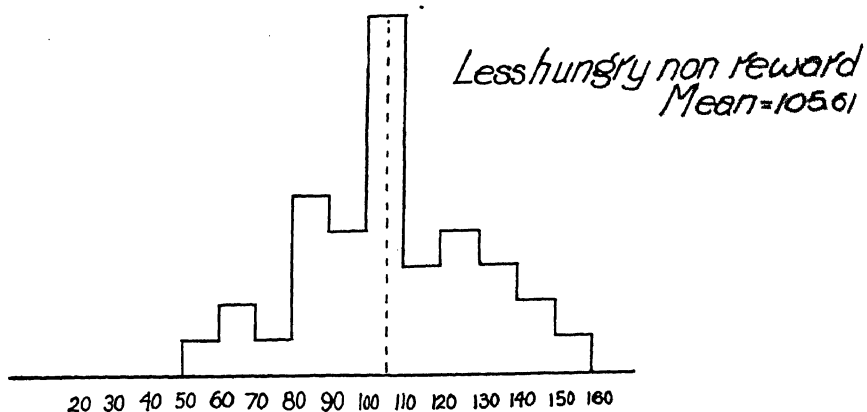
Errors

Fig. 4. Frequency Distribution of error scores.
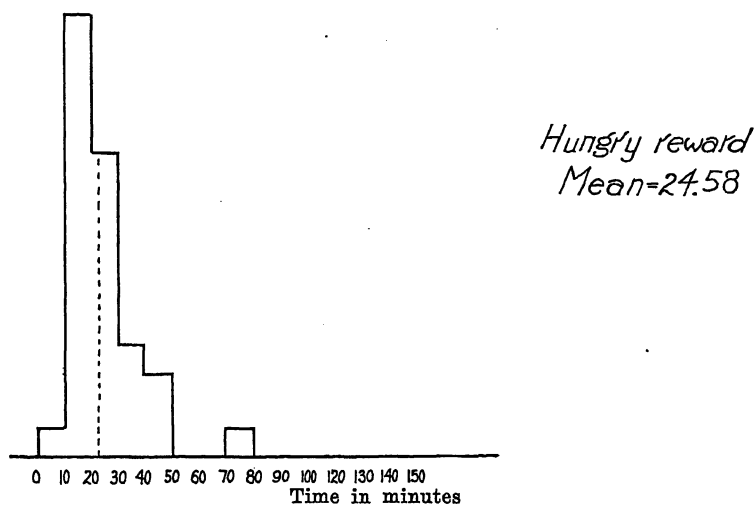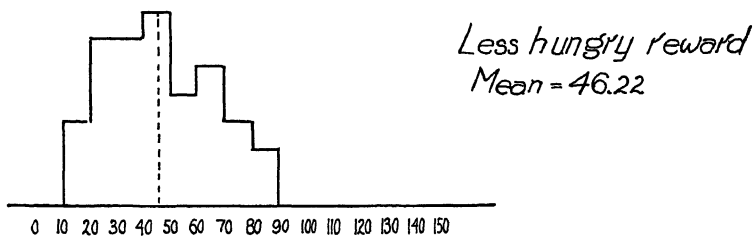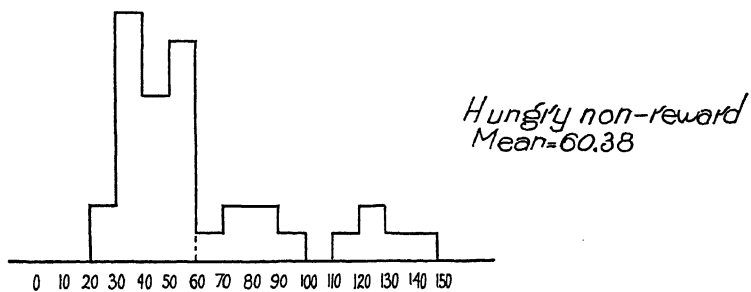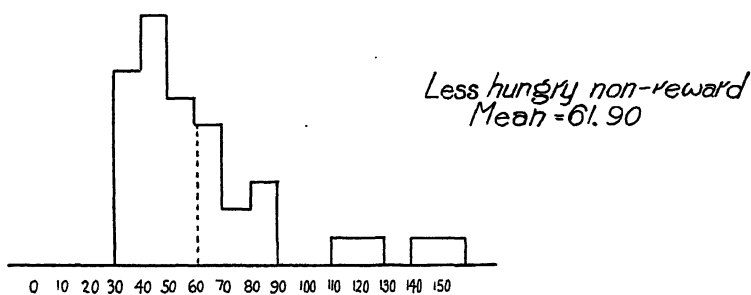
Fig. 5. Frequency distribution of time scores.

three curves, but particularly of the IINR and LHNR curves, and (2) the large drop in all these curves on the second day. (1) The upward trend of the time curves, when considered in connection with the error curves, means in general that, although the rats were making fewer errors on successive trials, they spent more time, i.e., moved more slowly or wandered about more in the true path and in the blinds. We may say that the rats had learned, to some degree, to avoid the blinds, but they still had no incentive to reach the end of the maze as soon as possible. (2) Time scores on the first day would naturally be high because of the rats' unfamiliarity with the maze and their consequent exploratory movements. The large drop on the second day in

Blinds pointing away from
food or outlet.

Blinds pointing toward
food or outlet.
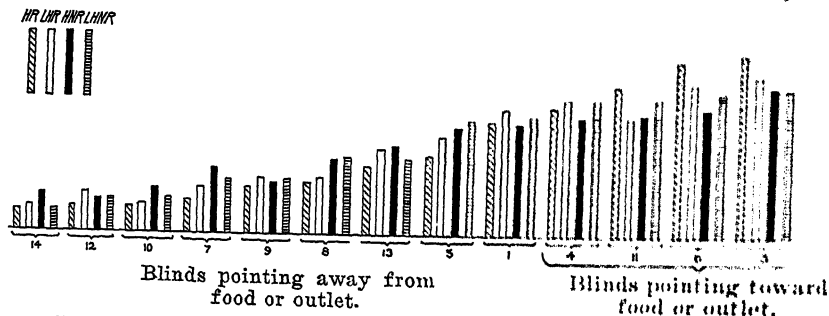
Fig. 6. Showing relative difficulty of blinds. Columns show per cent of total number of errors in each blind.

LHNR, HNR, and LHR curves is probably to be accounted for by a large reduction in errors, as indicated by the error curves.

Distribution of the rats as to error and time scores.—In order to give some idea as to the reliability of the group differences, frequency polygons have been constructed, which show the distribution of the rats both as to error scores (figure 4) and as to time scores (fig. 5).

The polygons based on error scores show a fairly even distribution of individuals. The polygons for time scores are, however, somewhat skewed. It is probable that a longer maze would have spread the time scores more evenly. It may be observed that the excessively long average time for the LHNR and HNR groups was in large part due to only a few individuals.

Tables.—In table 2 the critical ratios are to be read in connection with the frequency polygons. It will be seen that the differences in errors between all the groups, excepting that between the LHR and HNR are statistically significant. In other words, the differences between the groups were, with this one exception, not due to chance but are attributable to the differences, presence and absence of drive, presence and absence of reward.

TABLE 2

ERRORS

Group	Mean of Group	Sigmas of the distributions	Critical ratio with			
			LHNR	LHR	HNR	HR
LHNR	106	22.91	....	1.81	2.53	7.40
LHR	95	28.84	1.81	....	.70	4.86
HNR	90	30.00	2.53	.70	....	4.01
HR	69	25.28	7.40	4.86	4.01	....

In table 3 the differences in time between all groups, except that between LHNR and HNR, are significant.

TABLE 3

TIME

Group	Mean of Group	Sigmas of the distributions	Critical ratio with			
			LHNR	LHR	HNR	HR
LHNR	62	29.93	....	2.96	.21	6.94
LHR	46	19.82	2.96	....	2.28	5.59
HNR	60	31.65	.21	2.28	....	6.34
HR	25	12.00	6.94	5.59	6.34	....

In order to get some notion of the effect of *degrees of hunger, reward,* and *non-reward* on the *reliability* of the maze as a measure of individual differences, we have computed the reliability coefficients based on even-day scores *versus* odd-day scores for the four groups (table 4) (days 2–17).

TABLE 4

RELIABILITY COEFFICIENTS BASED ON EVEN-DAY *versus* ODD-DAY SCORES
IN ERRORS AND TIME

Group	Reliability coefficients for errors	Reliability coefficients for time
HR	.957 ± .009	.985 ± .003
HNR	.965 ± .007	.967 ± .007
LHR	.853 ± .030	.951 ± .010
LHNR	.858 ± .029	.882 ± .025

It will be noticed that the reliability coefficients based on *time* scores decrease as we pass from the HR Group to the HNR, LHR, and LHNR groups. However, only in the case of the LHNR Group as compared with each of the other three groups, is the difference between reliability coefficients large enough to be significant. We may conclude that so far as time scores are concerned the maze seems to be a more reliable instrument when both motive and reward are present.

Turning to the reliability coefficients based on error scores, we note that the coefficient for the HNR Group is slightly higher than that of the HR Group, contrary to what would be expected. But the coefficients for the LHR and LHNR groups are, as would be expected, somewhat lower. It appears that, for the maze and the conditions here used, the reliability of the maze so far as error scores are concerned is not reduced by absence of reward; absence of hunger, however, and absence of hunger with absence of reward, do reduce its reliability. In general, however, these reductions are surprisingly small.

RESULTS FOR INDIVIDUAL BLINDS

Relative difficulty of the blinds.—It will be seen by inspection of figure 1a that the blinds point in four directions, i.e., downward toward the entrance and exit, upward away from entrance and exit, to the right (in the general direction of exit and food), and to the left (away from exit and food). We may call these

blinds pointing downward or to the right, food-pointing blinds, and those pointing upward or to the left, non-food-pointing blinds. If there is any difference in difficulty between the two classes, as measured by the number of errors made in a blind, we should expect that the food-pointing blinds would be the more difficult. It has been shown by Dashiell[4] that rats very soon get a "notion" of the general direction of food and show a tendency to take openings pointing in that direction. In two studies soon to be published, Yoshioka[11] and Gengerelli[6] have come to the same conclusion, namely, that "rats are sensitive to a goal-direction in a maze, and a learning of the goal-direction plays a part in the maze solution." Borovski also has shown that, in a relatively simple maze in which all blinds point either forward or back, the forward-pointing, i.e., the food-pointing, blinds are much more difficult to eliminate than the backward-pointing blinds. Hence we should expect blinds pointing toward food to be entered most frequently and to be harder to eliminate. This expectation was substantiated.

Figure 6 is a bar diagram giving a graphic representation of the relative difficulty of the individual blinds. The height of each bar is based on per cent of total errors made in the blind represented by the bar. This figure is to be interpreted as follows:

(1) The blinds pointing down and to the right (food-pointing blinds) are by far the most difficult, five of these blinds having more than 50 per cent of all the errors in each of the four groups, as against the remaining nine blinds which in the case of each group have less than 50 per cent of the errors. Since two of the groups are "non-rewards," we must postulate an outlet-seeking impulse as well as a food-seeking impulse, because even for these non-reward groups, food-pointing (now merely exit-pointing) blinds are the most difficult, i.e., such blinds are most often entered.

(2) The Hungry Rewarded Group finds the five food-or-outlet-pointing blinds considerably more difficult than do the

other three groups. We are safe in saying that the condition, food and hunger, makes the food-pointing blinds more difficult than they are for the conditions, hunger and no food, less hunger and food, and less hunger and no food.

(3) The Less Hungry Rewarded Group also finds the food-or-outlet-pointing blinds more difficult than do the HNR and LHNR groups: these food-or-outlet-pointing blinds are, however, not as difficult for the LHR Group as they are for the HR Group.

Comparing the two groups, HR and HNR, we have the following distributions of errors for the two classes of blinds:

TABLE 4

Group	Errors in nine non-food-pointing blinds		Errors in five food-pointing blinds	
	Number	Per cent	Number	Per cent
HR	838	.366 ± .006	1448	.634 ± .006
HNR	1541	.477 ± .005	1689	.523 ± .005

For the HNR Group the distribution of errors among the two classes of blinds is nearly equal, 48 per cent and 52 per cent. In the HR Group there is a decided shifting from the 50-50 proportion, i.e., the percentages are 37 per cent for non-food-pointing blinds and 63 per cent for food-pointing blinds.

This shifting from the 50–50 proportion, or the greater piling up of errors by the HR Group in the food-pointing blinds is undoubtedly due to the greater "interest" of the rewarded rats in the direction of food. The greater the "interest" in the goal the more difficult goal-pointing blinds become.

CONCLUSIONS

1. Hungry rewarded rats, as measured both by time and errors, learned the maze more rapidly than did the other three groups.

2. Less hungry non-rewarded rats had time- and error-curves that indicated the slowest elimination of blinds and an actual increase in time on successive runs.

3. Less hungry rewarded rats and hungry non-rewarded rats had error curves that indicated approximately the same amount of learning. But the time curve of the HNR rats was closely comparable to the time curve of the LHNR Group.

4. Hunger and food reward, or in more general terms, drive and the possibility of its satisfaction, are the two factors which, when both are present, produce the most rapid learning. On the other hand, absence of both these factors causes the slowest learning. Lack of drive (hunger) with the presence of its normal satisfaction (food), and presence of drive (hunger) with absence of its satisfaction (food), as measured by the error curve, produced, under the conditions of this experiment, overt learning in approximately equal amounts.

5. So far as time scores are concerned, the maze used in this experiment affords a reliable measure of individual differences in maze-learning ability under all conditions, except the less-hungry non-reward condition. In the case of error scores, reward and non-reward (with hunger) both gave reliable results under the conditions used.

6. The maze also appeared to afford a good measure of group differences, as indicated by the frequency polygons for error and time scores.

7. The blinds in the maze are divided into two kinds on the basis of difficulty of learning (elimination). This division appears to correspond closely with a division based on the direction in which the blinds point. But it is not asserted that *greater* difficulty of learning is caused entirely, or even mainly, by the fact that blinds point *toward food or exit*. Other factors besides food and exit *may* help to make the food-exit-pointing blinds more difficult to eliminate.

LITERATURE CITED

[1] ANDERSON, J. E., and SMITH, A. H.
  1926.   The effect of quantitative and qualitative stunting on maze learning in the white rat. *Jour. Comp. Psychol.*, 6:337–359.

[2] BLODGETT, H. C.
  1929.   The effect of introduction of reward upon maze performance of rats. *Univ. Calif. Publ. Psychol.*, 4:113–134.

[3] BOROVSKI, W. M.
  1927.   Experimentelle Untersuchungen über den Lernprozess. (Labyrinth studien an weissen Ratten.) *Zt. f. Verg. Physiol.*, 6:489–529.

[4] DASHIELL, J. F.
  1930.   Direction orientation in maze running by the white rat. *Comp. Psychol. Mon.*, 7: no. 2.

[5] ELLIOTT, M. H.
  1929.   The effect of appropriateness of reward and of complex incentives on maze performances. *Univ. Calif. Publ. Psychol.*, 4:91–98.

[6] GENGERELLI, J. A.
    The principle of maxima and minima in animal learning. MS.

[7] GRINDLEY, G. C.
  1929.   Experiments on the influence of the amount of reward on learning in young chickens. *Brit. Jour. Psychol., General Section*, 20:173–180.

[8] TOLMAN, E. C., HONZIK, C. H., and ROBINSON, E. W.
  1930.   The effect of degrees of hunger upon the order of elimination of long and short blinds. *Univ. Calif. Publ. Psychol.*, 4:289–302.

[9] WARDEN, C. J., and HAAS, E. L.
  1927.   The effect of short intervals of delay in feeding upon speed of maze learning. *Jour. Comp. Psychol.*, 7:107–116.

[10] WILLIAMS, K. A.
  1929.   The reward value of a conditioned stimulus. *Univ. Calif. Publ. Psychol.*, 4:31–55.

[11] YOSHIOKA, J. G.
    Direction as a factor in maze solution in rats. MS.

INTRODUCTION AND REMOVAL
OF REWARD, AND MAZE PERFORMANCE
IN RATS

BY

E. C. TOLMAN and C. H. HONZIK

INTRODUCTION

Experiments by Blodgett,[1] Simmons,[5] Szymanski,[6] Williams,[9] and Elliott,[3] have shown that, if rats begin the learning of a maze with no reward, or with only a slightly effective reward, and then at a later stage a more effective reward is introduced, sudden drops in the error and time curves appear. These drops seem to testify to a *latent learning* acquired during the non-reward or poorly rewarded period, a learning which is made manifest only after the introduction of the more effective reward.

A reverse phenomenon has also been recently demonstrated. Elliott[3] obtained a sudden rise in the performance curves when an originally effective reward was removed, and a less effective one substituted. Since the completion of the experiments to be reported here, Bruce[2] and Sharp[4] have also presented findings similar to those of Elliott. They all found a disintegration in the performance directly subsequent to the removal of an initial reward.

The present experiment was designed to examine both types of phenomena, and especially to analyze them with respect to entrances into food-(exit)-pointing and into non-food-(non-exit)-pointing blinds, considered separately.

APPARATUS AND METHODS

Maze.—The maze was a 14-unit T-maze, used in the previous study.[8] (See fig. 1.)   The arrangement of the blinds is shown in figure 1a.

General procedure.—Eighty-two male rats, divided into two groups of 41 rats each, were run in the maze.   One group was
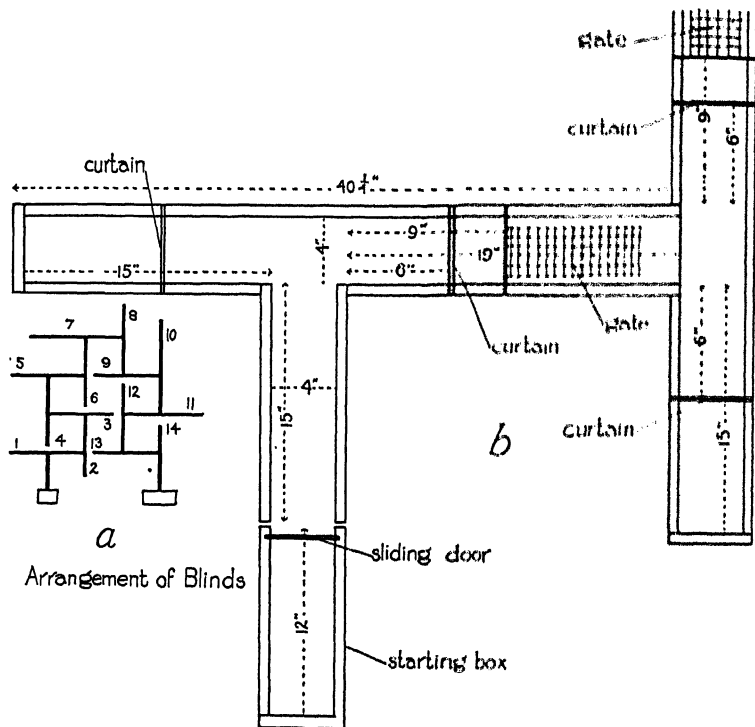
Fig. 1.

called the Hungry Reward-Non-reward (HR-NR) Group, the other, the Hungry Non-reward-Reward (HNR-R) Group.

Preliminary training.—This accustomed the rats to being handled, and taught them to manipulate the gates and curtains before being run in the maze itself.   It involved the use of a

straightaway and a single T-unit for five days and was in every way identical with that of the previous study.[8]

Training proper.—This consisted, for the two groups, of one run a day in the 14-unit maze for 22 days. For the *Hungry Reward-Non-reward* (*HR-NR*) *Group* a food reward was given at the end of each run from the first to the tenth day, inclusive. On the eleventh day of training food was withdrawn, and the rats ran into end boxes that had never contained food of any sort but were in all physical aspects like the real food boxes. It should be noted that this eleventh day, although no food was in the end box, belongs with the first ten days, i.e., in the reward period, since the rats did not know, when they started this day's run, that no food was to be had. The non-reward period extended, then, from the twelfth to the twenty-second day, inclusive. During this period the rats were fed in their living cages (one rat in a cage) not less than three hours nor more than four hours after the completion of the day's run. The amount of the daily food ration during the total 22-day period was adjusted to the weight of the rat and was such that the rats lost weight in various degrees (i.e., from 10 to 32 grams), depending somewhat on initial weight. (Table 1.)

For the *Hungry Non-reward-Reward* (*HNR-R*) *Group* no food was given in the end boxes from the first to the tenth day inclusive. The rats were fed during this period, in their living cages, not less than three hours after the day's run, as in the non-reward period of the other group. On the eleventh day food was placed in the end boxes. Again it should be noted that this eleventh day belongs with the first ten days, since the rats did not know at the beginning of the run that they would be rewarded. The reward period extended therefore from the twelfth to the twenty-second day inclusive. Throughout the total 22-day period the rats were fed in proportion to their weight so as to keep them hungry. (Table 1.)

The daily runs were given as nearly at the same hour of the day as was possible; actually the fluctuations in this respect,

TABLE 1

INITIAL WEIGHTS AND LOSSES IN WEIGHT IN GRAMS DURING TRAINING

Hungry Reward-Non-reward			Hungry Non-reward-Reward			Hungry Reward-Non-reward			Hungry Non-reward-Reward		
Rat No.	In. Wt.	Loss	Rat No.	In. Wt.	Loss	Rat No.	In. Wt.	Loss	Rat No.	In. Wt.	Loss
W26	110	10	W27	110	8	H4	150	20	H8	145	20
W49	110	10	W34	120	15	W50	152	22	H13	146	28
G7	110	12	W23	120	12	W48	154	21	G3	150	18
H15	112	14	W22	120	15	G2	158	18	H11	150	25
W21	118	8	H5	122	12	B13	160	30	W36	150	21
W63	120	20	W33	122	14	W30	160	28	W32	154	24
W42	125	16	W57	130	20	W65	170	30	G6	156	26
H7	125	15	W54	132	19	W73	170	31	W46	160	18
B4	128	20	W31	132	20	B12	170	28	B7	160	15
W56	130	20	W55	133	16	W70	182	30	B9	164	18
W61	132	21	B3	133	12	W25	184	24	W24	164	24
W60	135	16	W21	134	14	H30	184	25	H9	165	19
H12	136	25	H?	135	16	H21	190	32	H14	174	30
H6	138	26	W35	140	20	W?	190	26	H16	174	29
W43	140	20	W45	140	16	W67	200	25	W64	175	26
W40	142	24	W44	142	17	W71	200	27	W58	175	30
W62	143	23	H10	142	12	W69	214	32	B11	190	29
W41	144	24	W59	142	20	W72	214	26	B10	196	26
W39	150	20	G1	145	21	W68	230	30	H17	196	32
W47	150	24	W53	145	15						

when they occurred, did not extend beyond one hour. Small sections of both groups were run concurrently. This assured that improvements in technique, or other changes, if any, would affect both groups equally.

The rats.— The rats of the two groups were males $3\frac{1}{2}$ to 5 months old, without any previous training, and of mixed coat-color, some being hooded, others black, but most being white. The coat-colors were fairly equally distributed by chance between the two groups. The rats at the beginning of the experiment were all healthy and in good condition. As against the 82 rats that completed the training four were discarded because of illness and three were discarded because for unknown reasons they refused to run.

Scoring. Time and error records were kept. An entrance into a blind the full body length (not including the tail) was considered an error. No attempt was made to record degrees of entrance. A second or third entrance into a blind during the same run was also considered an error and included in the records. Returns into units just traversed were prevented by the gates; thus this type of error is not present in our maze.

The blinds in the maze were numbered in order from the first to the fourteenth, and each error was recorded by the number of the blind in which it was made. A convex mirror over the maze made it possible to see the movements of the rat in any part of the maze.

GROSS QUANTITATIVE RESULTS

Hungry Reward Non reward Group.— Figure 2 presents the learning curves based on error scores of the HR-NR Group as compared with two other groups, namely, a Hungry Reward (HR) Group, and a Hungry Non reward (HNR) Group. The two latter groups were parts of the previous experiment[8] in which the same maze was used and other conditions were the same, save that these other groups were run at an earlier time. Each of the latter two groups consisted of 36 (instead of 41)

rats, but the three curves of figure 2 are comparable since they are in terms of average numbers of errors.

Examination of the three curves brings out the following points: First, the rate of learning of the HR-NR Group during the reward period was approximately equal to that of the HR Group during the same eleven-day period. If anything, the HR-NR Group learned a little more rapidly from the third to
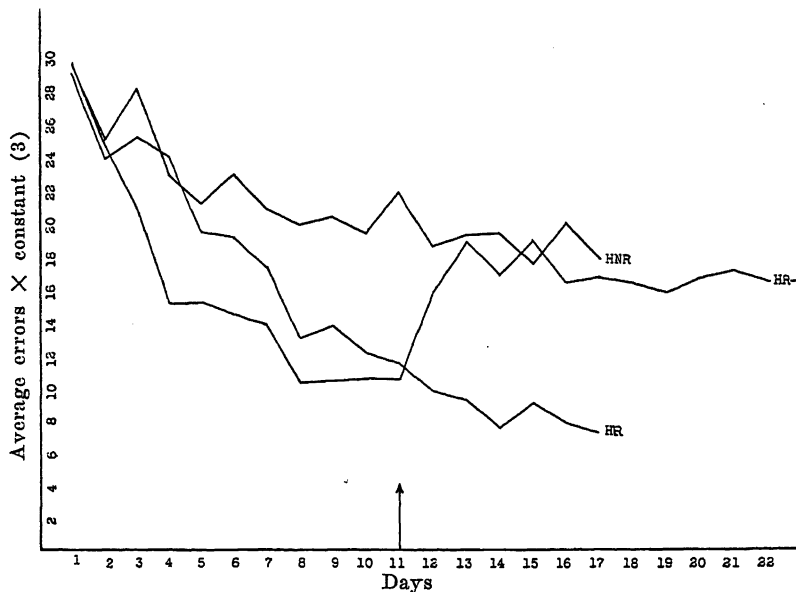
Fig. 2. Error curves for HR, HNR, and HR–NR.

the eighth day. Secondly, on the day following the removal of reward, that is, the twelfth day, there is a sudden rise in the curve. This rise is continued on the thirteenth day. Thirdly, the level reached by this sudden rise corresponds closely to the level of the HNR Group at the same stage of the training.

Figure 3 presents the time curves of the three groups. The same three points are to be noted but with certain modifications. First, the rise in the time curve of the HR-NR Group, when reward was removed, does not appear to be so sudden. Secondly, the time curve, after removal of reward, does not reach that of the HNR Group.

With regard to the error curve of the HR-NR Group it is to be noted that the sudden increase in number of errors on the day following removal of reward is equal to 53 errors, or an average increase per rat of 1.3 error. The increase on the next day equals 32 errors, an average of about .75 error per rat. During the *reward* period of this group there were slight rises in the curve on the fifth, ninth, and tenth days. But in each case the rise was
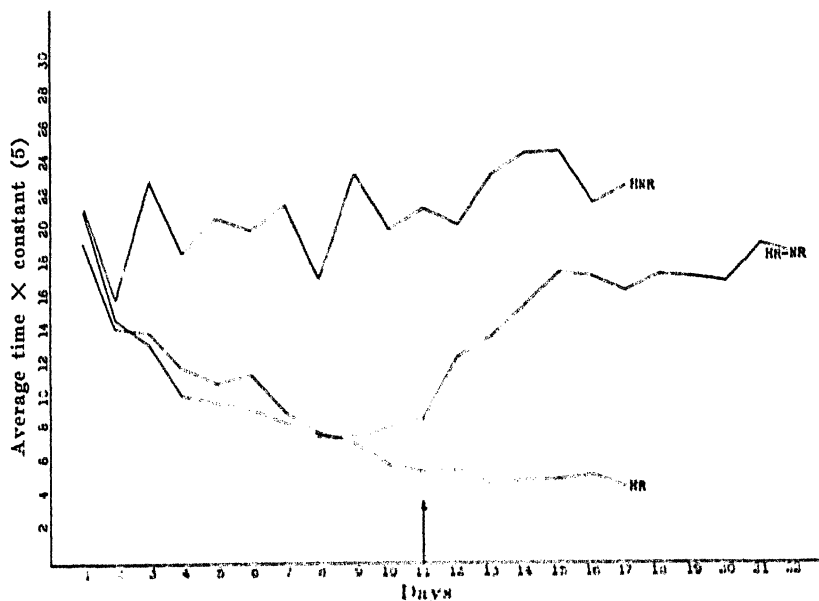
Fig. 3.   Time curves for HR, HNR, and HR-NR.

equal to only one error, or an average per rat of .25 error. There are, however, larger upward jumps in the HR Group on the third, ninth, and fifteenth days. Of these the largest is that of the fifteenth day, and amounts to 15 errors (average, .42 error). To show that the average rise on the twelfth day in the HR-NR curve is significantly larger than the average jump of the HR curve we must compare the two jumps as to their standard deviations. These comparisons are given in table 2.

A critical ratio of 2.23, interpreted in terms of probability, means that a difference between the two upward jumps as large as that obtained would occur by chance about 1.4 times in 100

times, or slightly less than one-seventieth of the time. It is therefore fairly certain that the rise on the twelfth day of the HR-NR error curve was due to the removal of reward and not to ordinary chance factors such as produce occasional rises in the curve for the HR Group.

Although a full day intervened between the time the rats made their first non-rewarded runs and the next succeeding runs, there was evidently a decided memorial effect of the previous foodless run twenty-four hours before, as was evidenced by the searching of blind alleys normally avoided; and hence the increase in number of errors.

TABLE 2

MEAN ERRORS

	Mean rise in errors	Difference between the two rises	σ difference	Critical ratio
HR Days 14-15..............................	.4166	.8761	.3931	2.23
HR-NR Days 11-12.........................	1.2927			

In the time curve of the HR-NR Group the *average* upward jumps on the twelfth, thirteenth, fourteenth, and fifteenth days were equal (using whole numbers) to 37 seconds, 13 seconds, 18 seconds, and 4 seconds, respectively. During the *reward* period of this group there were also *average* rises on the tenth and eleventh days equal to 6.6 and 6.0 seconds, respectively. To show that the upward jump on the twelfth day was larger than can be accounted for by chance factors, it is necessary to compare this jump with the largest, i.e., the 6.6-second jump, in the reward period, or with the largest rise in the curve of the control HR Group. The largest rise in the HR curve, however, is less than the largest jump in the reward period of the HR-NR Group, and we have therefore taken for comparison the 6.6-second rise of the HR-NR Group, reward period. The results of the comparison are given in table 3.

The critical ratio of 2.84 indicates that the difference obtained would occur by chance about .26 times in 100. We are therefore safe in concluding that the rise in time on the twelfth day was due to the removal of food and not to chance factors.

Hungry Non-reward-Reward (*HNR-R*) *Group.*—Figure 4 shows the error curves of the HNR-R Group as compared with the same two control groups used with the HR-NR Group. It will be noted first that during the non-reward period of the HNR-R Group, there is a downward trend of the curve similar to that of the HNR Group. Secondly, on the twelfth day there is a large drop. And thirdly, this drop, plus the one on the

TABLE 3
MEAN TIME SCORES

	Mean rise in seconds	Differences between the two rises	σ difference	Critical ratio
HR-NR-Days 9-10........	6.6			
		30.25	10.65	2.94
HR-NR-Days 11-12.......	36.85			

thirteenth day, brings the curve considerably below that of the HR Group at the same stage of the training. This drop in the HNR-R curve *below* the HR curve raises an interesting question.

The non-reward period of the HNR-R Group was undoubtedly a period of latent learning. Does the drop of the HNR-R curve *below* the HR curve, when reward is introduced, mean that this latent learning was more effective than the overt learning of the HR Group during the same period of time? To get some statistical information on the reliability of the difference between the two curves *from the twelfth day on*, the error scores for the two groups (HR and HNR-R) were taken and the critical ratio between the two computed. It was found to amount to 2.205. It would therefore appear that the difference was a statistically significant one. We are not ready, however, to state with any certainty that this was due to the greater efficiency of

the latent learning. Other factors may have influenced the situation. It may have been that the rats of the HNR-R Group were brighter as regards maze learning than the HR Group. But the possibility that it was due to the greater efficiency of latent learning remains.

We turn next to a comparison of the drop in the HNR-R *error* curve on the twelfth day with the largest drop either in the non-reward period in the HNR-R curve or in the HNR curve. The largest drop happens to be on the second day of the HNR Group. Table 4 gives the results of this comparison.

TABLE 4

MEAN ERRORS

	Mean drop in errors	Difference between the two drops	σ difference	Critical ratio
HNR-Days 1-2...............................	1.1			
		1.0	.418	2.40
HNR-R-Days 11-12......................	2.1			

A difference between the two drops in the error curves as large as that found here would occur by chance about .8 times in 100. We may conclude that the drop in error scores was due to the introduction of reward.

Turning now to the time curve of the HNR-R Group (fig. 5), we note again the large drop in time on the twelfth day. During the non-reward period the HNR-R curve was approximately on the same level with the HNR Group. But the drop in time on the introduction of reward did not bring the curve significantly *below* the HR curve, as was the case with the error curve of the HNR-R Group.

Table 5 gives the comparisons between the twelfth day drop of the HNR-R curve and the drop on the second day of the HNR curve, which happens to be larger than any other drop in the HNR-R curve during the non-reward period.
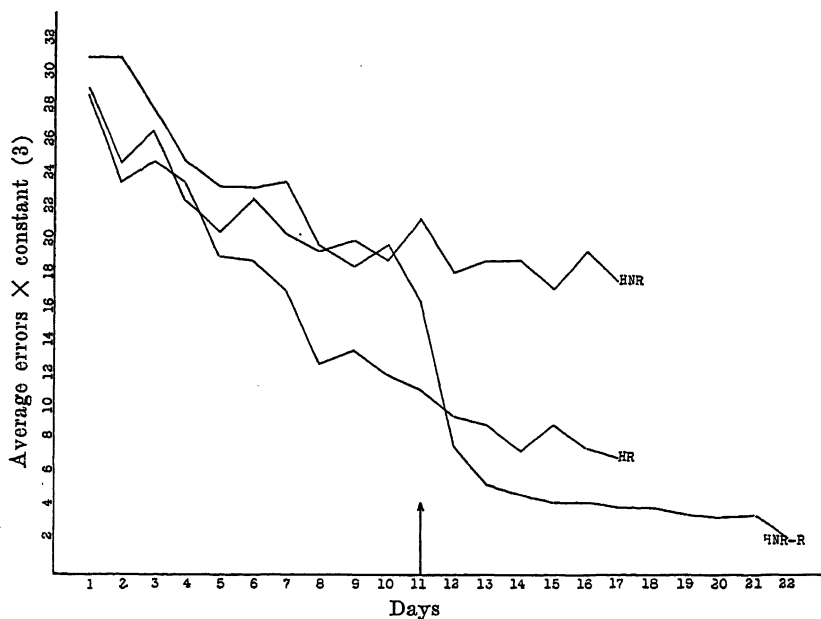
Fig. 4.   Error curves for HR, HNR, and HNR–R.
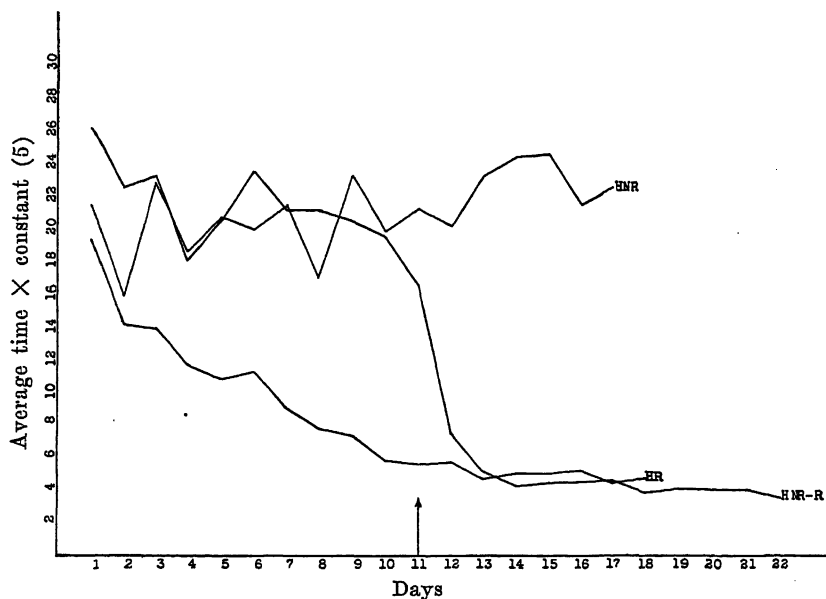
Fig. 5.   Time curves for HR, HNR, and HNR–R.

The critical ratio of 2.83 warrants the statement that the twelfth-day drop in the HNR-R curve was undoubtedly due to the introduction of reward.

TABLE 5

MEAN TIME SCORES

	Mean drop in time	Difference between the two drops	σ difference	Critical ratio
HNR-Days 1-2	54 sec.	37 sec.	13.07	2.83
HNR-R-Days 11-12	91 sec.			

RESULTS FOR INDIVIDUAL BLINDS

The second question set for the present experiment was in regard to the effects in individual blinds. Stated in other words, the question is, does the introduction or removal of reward change the difficulty of some blinds more than others?

Hungry Reward-Non-reward Group. Figure 6 is a bar diagram representing the relative difficulty of the fourteen blinds of the maze. The height of each bar is based on the per cent of total errors made in the blind represented by the bar. The blinds (solid bars) are arranged in increasing order of difficulty from left to right as this order was determined during the *reward period.* It will be noted that the last five blinds to the right of the figure are the most difficult. These five blinds point either down or to the right, that is, in the general direction of food (see fig. 1a). These same five blinds were found to be the most difficult in the previous study; and it was there concluded that, of the factors determining the order of difficulty of blinds, the direction in which the blind points is one of the more influential.

Besides the solid bars, cross-hatched ones are given. These show the relative difficulty of blinds during the *non-reward period* and indicate the changes in difficulty produced by the change from reward to non-reward. Three points are to be

noted: *First,* blind 1 appears to have increased in difficulty more than any other. *Secondly,* all the food-pointing blinds, i.e., the last five blinds in the figure, except blind 11, decreased in difficulty. *Thirdly,* all the non-food-pointing blinds, except blinds 9 and 13, increased in difficulty.

These three points are subject to interpretations which unfortunately must be largely anthropomorphic. Our general experience with maze learning by rats has convinced us that the first blind in the maze is always quite difficult; it is always above the average in difficulty. Observation of the rat's behavior in the maze indicates that the difficulty of the first blind, i.e., the large
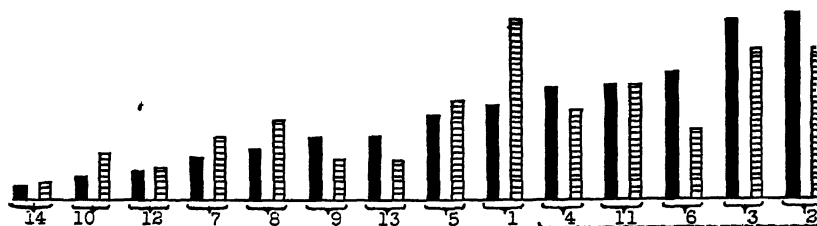
Fig. 6. Showing relative difficulty of blinds in reward and non-reward periods.

number of entrances into this blind, is due largely to the nervous behavior of the rat when he first enters the maze—a behavior often present even in the later stages of learning and characterized by slow or rapid exploration of the first unit as if the rat were seeking his bearings. Even rats that run through the remainder of the maze with great speed and few errors very often make this preliminary exploration. It would seem probable, therefore, that the large increase in difficulty of blind 1 on the removal of reward may have been due merely to an increased cautiousness and hence to a greater exploration of the first unit. The non-rewarded run on the previous day would appear to make the rat more anxious to get started correctly.

The second fact, that the blinds that were difficult during the reward period become less difficult on the removal of reward, again, must be interpreted somewhat anthropomorphically. These blinds no longer point toward food since the food has been

removed. There is no longer the drive toward a goal which was in a definite position. There is on the contrary a tendency to seek in other directions.

Finally, the third fact of the increase in difficulty of the blinds which were previously non-food-pointing would be a corollary of the above second fact. The rats now begin hunting in these other blinds. Such a positive hunting was also discovered by Bruce.[2]
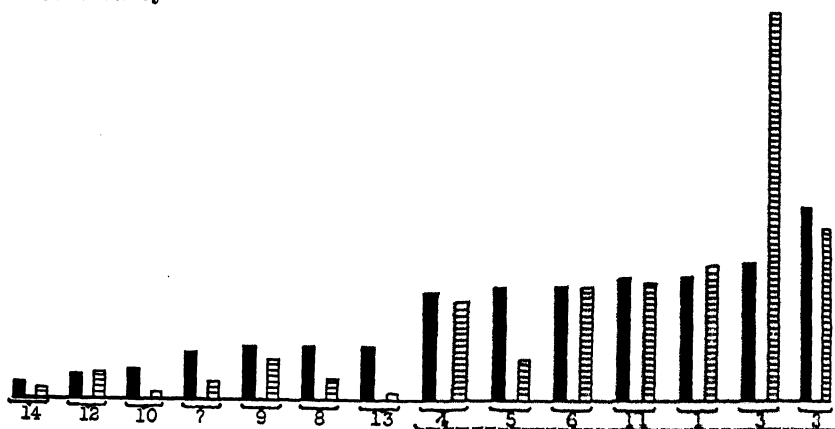
Fig. 7.   Showing relative difficulty of blinds in reward and non-reward periods.

Hungry Non-reward-Reward Group.—Figure 7 indicates graphically the relative difficulty of the blinds during the non-reward and reward periods of the HNR-R group. Here the blinds (solid bars) are arranged in ascending order of difficulty as this was determined during the period of *non-reward*. It will be noted that with no reward the blinds have approximately the same order as was obtained during the *reward period* of the HR-NR Group. The food-pointing—in this case the exit-pointing—blinds are again the most difficult ones, except for blinds 1 and 5 which have become more difficult and are in this respect like the food-pointing group. Aside from this exception, it appears that blinds may be divided into two classes, as regards difficulty, on the basis of the direction in which they point. But since in the non-reward period the blinds do not point to food, we

must postulate an exit-seeking as well as a food-seeking drive in maze learning, as was also done in the previous study.

Two other points are to be noted. First, there was no increase of entrances into food-pointing blinds when reward was introduced, except for blind 3, which shows an enormous increase. Secondly, all the non-food-pointing blinds, except 1 and 12, show decrease in difficulty, i.e., in number of entrances. In the case of blinds 10 and 13 this decrease is particularly striking.

The great increase of entrances into blind 3 on the introduction of reward may reasonably be accounted for by the increased drive in the direction of the exit which now provides not only escape from the maze but food besides. But why was there no similar increase in the other food-pointing blinds? The present data do not furnish any clear answer.

The large decreases in difficulty of non-food-pointing blinds may be accounted for by the same assumption mentioned above, namely, that introduction of reward increases the strength of the drive toward food so that there is less tendency to enter blinds pointing away from food.

Table 6 shows the *changes* in percentages of total errors made in the two classes of blinds when a change is made from reward to non-reward, and from non-reward to reward. Thus, for the HR-NR group, the five food-pointing blinds had 61 per cent of the errors during the reward period, while during the non-reward period the per cent was 49. For the HNR-R Group, the errors in the five food-pointing blinds were 56 per cent during the non-reward period, and rose during the reward period to 75 per cent.

TABLE 6

PERCENTAGE OF TOTAL ERRORS MADE IN THE FOOD-POINTING AND THE NON-FOOD-POINTING BLINDS DURING REWARD AND NON-REWARD PERIODS

Hungry Non-reward-Reward Group				Hungry Reward-Non-reward Group			
Non-reward period		Reward period		Reward period		Non-reward period	
Food-pointing blinds	Non-food-pointing blinds	Food-pointing blinds	Non-food-pointing blinds	Food-pointing blinds	Non-food-pointing blinds	Food-pointing blinds	Non-food-pointing blinds
.56±.006	44±.006	.75± 013	.25±.013	.61±.007	.39±.007	.49±.007	.51±.007

RELIABILITY COEFFICIENTS OF THE MAZE FOR REWARD AND NON-REWARD PERIODS

To get some idea of the reliability of the maze under reward and non-reward conditions, we have computed the reliability coefficients based on odd-day versus even-day scores for both error and time scores. These are given in table 7.

TABLE 7

Reliability Coefficients Based on Even-Day *versus* Odd-Day Scores in Errors and Time

Group	Reliability coefficients for error scores	Reliability coefficients for time scores
HR-NR (Reward period)	.962 ± .008	.965 ± .007
HR-NR (Non-reward period)	.937 ± .013	.876 ± .024
HNR-R (Non-reward period)	.894 ± .021	.954 ± .011
HNR-R (Reward period)	.956 ± .009	.903 ± .019

It will be noticed that the reliability coefficients both for error scores and time scores are, with one exception, higher for the reward period than for the non-reward period. The differences between r's in two cases, namely, between the r's of the NR and R periods of the HNR-R Group for error scores, and between the r's of the R and NR periods of HR-NR Group for time scores, are large enough to be significant. It may be concluded that under reward conditions the maze is a more reliable instrument for the measuring of learning ability than under non-reward conditions. But it must be pointed out that in the previous study a hungry rewarded group of rats had a reliability coefficient for errors slightly lower than that of a hungry non-rewarded group.

SUMMARY

1. Rats run with food reward at the end of the maze showed, when reward was removed, large increases in both time scores and error scores, which could not be accounted for by chance factors alone.

2. Rats run without reward, when reward was introduced, showed large decreases in both time scores and error scores, which also could not be accounted for by chance factors alone.

3. The drop in the error curve for the group of rats that were rewarded on the eleventh day brought the curve significantly below the curve of a control group of rats that had been rewarded from the first. This suggests that latent learning may be more effective than overt learning.

4. Removal of reward after a period of reward changed the relative difficulty of blinds.

   (a) The first blind became especially difficult.

   (b) Non-food-pointing blinds became relatively more difficult than they were during the reward period.

   (c) Food-pointing blinds became relatively less difficult than they were during the reward period.

5. Introduction of reward after a period of non-reward likewise changed the relative difficulty of blinds.

   (a) Non-food-pointing blinds became relatively less difficult during the reward period.

   (b) Food-pointing blinds changed very little in difficulty when reward was introduced. But one food-pointing blind, number 3, increased very greatly in difficulty.

6. Reliability coefficients based on even-day versus odd-day scores in errors and time indicate that the maze is a more reliable instrument under reward conditions. But even under non-reward conditions the reliability coefficients were surprisingly high.

LITERATURE CITED

1 BLODGETT, H. C.
   1929. The effect of introduction of reward upon the maze performance of rats. *Univ. Calif. Publ. Psychol.*, 4:115–134.

2 BRUCE, R. H.
   1930. The effect of removal of reward on the maze performance of rats. *Univ. Calif. Publ. Psychol.*, 4:203–214.

3 ELLIOTT, M. H.
   1928. The effect of change of reward on the maze performance of rats. *Univ. Calif. Publ. Psychol.*, 4:19–30.

4 SHARP, W. S.
   1929. Disintegrative effects of continuous running and removal of the food incentive upon the maze habit of albino rats. *Jour. Comp. Psychol.*, 9:405–423.

5 SIMMONS, R.
   1924. The relative effectiveness of certain incentives in animal learning. *Comp. Psych. Mon.*, 2: no. 7.

6 SZYMANSKI, J. S.
   1918. Ein experimenteller Beitrag zur Analyse der bei Entstehung neuer Gewohnheiten mitwirkenden Faktoren. *Pflüger's Arch. f. d. ges. Physiol.*, 170:197–220.

7 TOLMAN, E. C., HONZIK, C. H., and ROBINSON, E. W.
   1930. Effects of different degrees of hunger and of reward and non-reward on time and error elimination in maze learning by the rat. *Univ. Calif. Publ. Psychol.*, 4:189–202.

8 TOLMAN, E. C., and HONZIK, C. H.
   1930. Degrees of hunger, reward and non-reward in maze performance of rats. *Univ. Calif. Publ. Psychol.*, 4:

9 WILLIAMS, K. A.
   1927. The reward value of a conditioned stimulus. *Univ. Calif. Publ. Psychol.*, 4:31–55.

THE RÔLE OF KINESTHESIS IN
MAZE LEARNING

BY

D. A. MACFARLANE

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—Warner Brown and Edward C. Tolman, Editors.

Price per volume, $3.50.

THE RÔLE OF KINESTHESIS IN MAZE
. LEARNING[1]

BY

D. A. MACFARLANE

The vogue of the concept of kinesthesis as the explanatory factor in maze learning, it is probably safe to say, dates from the experiments of Watson, and of Carr and Watson, in 1907 and 1908. These workers offered the thesis that, when a rat learns a maze all he does is to condition his responses to the precise proprioceptive cues afforded by the running itself. This point of view, thus growing out of direct experimentation, has now become firmly entrenched in all discussions of the problem. And its position has been strengthened by more general lines of theoretical reasoning. For the philosophy of the neurologizing psychologist has led, upon development, to explanatory principles which also employ reflex-like concepts such as are implied in this doctrine of kinesthesis. Moreover, but slightly at variance with these are the teachings of Thorndike and his followers, with their implied specificity of the S-R bond.

It seems, however, to an unbiased observer, that to consider the vast majority of the acts which constitute ordinary behavior, as resulting from the precise linkage of receptor and effector by means of more or less fixed nerve paths, is to distort the facts beyond recognition. For the most part such criticisms of the notion of specific linkages have come from outside the immediate field of animal behavior, but in the last few years insurgent voices have been raised from within the animal laboratory itself.

This paper will attempt to show that, although it is probable that kinesthesis, as the term is usually employed, determines to some extent *how* a rat will travel through a maze, it does not determine *where* he will go.

HISTORICAL BACKGROUND

The experiments of Watson[10] and of Carr and Watson[4] are familiar to all. In the first series of experiments the animals were operated upon to eliminate, in succession, the vibrissae, the hearing, the sight, and the tactual sensations through the feet. None of these operations disturbed the learning process to any appreciable extent. In the second series of experiments, normal animals that had already learned the maze were introduced into it at various points along the true path. The immediate exploration required by most of the animals for orientation under these circumstances, was interpreted by the workers as movements necessary to provide the kinesthetic stimulations that would release the automatic movements,[2] which had been acquired. Next came the sectioned maze of Carr and Watson in which it was possible to lengthen or shorten certain alleys without altering the relations of turns to alleys. The resulting pronounced disturbances in the running were attributed by the experimenters to interference with the previously developed kinesthesis.

In a few studies the results argue against the doctrine of kinesthesis. Hunter[6][7] taught rats to make simple alternations in a T-shaped discrimination box, that is, he taught them to make successive choices in accordance with the formula *lrlrlr*. No rat, even after a prolonged practice period, was able to follow the plan *llrrllrrllrr*, that is double alternations. Hunter then arranged his "temporal maze" (i.e., the T-box modified so

---

[2] It is to noted that Hunter,[7] years later, accounted for the failure of the animals immediately to orient themselves by assuming, not that they must of necessity get into the kinesthetic swing of things, but that they had to seek some cue whereby to orient themselves with regard to the general spatial relationships of the total situation.

that the animal is fed only after a whole series of successive choices, instead of after each choice) in order to determine whether the animals practiced on a conventional, spatial maze where the order of turns was *llrrllrr*, and so on, could carry the plan over to successive runs on this temporal maze. No rat was able to make this transfer. With still another group, the problem was to learn simple alternation in the temporal maze. Only one animal learned the lesson. Kinesthesis for this animal was then varied by placing baffles through the alleys; the animal was disturbed by this device for one run, but thereafter ran normally. Hunter remarks, "A given kinesthetic complex may mean either of several responses but it cannot mean now one and now another without the addition of some selective element. . . . ." Higginson[5] forced the rats to run into a cul and out again before running the rest of the maze. This was done by closing the entrance to the maze, located beside the entrance to the cul, while the rats were entering the cul, and opening it when they returned. Later, when the door to the maze was left open from the beginning of the run, the rats entered the maze without first traversing the cul. Higginson is correct in saying that this behavior "is wholly inexplicable in the usual categories of 'kinesthetic patterns' and 'frequency and recency' of performance," and it is in fact the expected behavior when a rat is confronted with an open door that had not been a part of the familiar situation.

A few fragmentary bits may be gleaned from the data of experiments not concerned primarily with the problem at hand. In one of Lashley's studies on cerebral function in learning[8] is the account of the behavior of one of his animals which, owing to the fortuitous results of an operation, displayed the forced movements commonly associated with labyrinthine lesions, in that it was unable to turn to the left. When retested on the discrimination box following the operation, the animal compensated by rotating 270 degrees to the right whenever the task demanded a turn of 90 degrees to the left. In another study Lashley and McCarthy[9] investigated the survival of the maze habit after

cerebellar injuries. Many of the animals showed perfect reten-
tion records in spite of the fact that, owing to the operation,
their methods of locomotion were much interfered with. Thus
one of them "walked as if drawing a heavy weight, with fore
and hind legs extended forward and dragging her along in a
series of lunges," yet still showed a perfect series of choices.

STATEMENT OF THE PROBLEM

In the experiment of Watson and Carr, the implication is
evident that the only variable introduced was the change in the
proprioceptive pattern. One could maintain, however, with
some justification, that, so far as the total problem was con-
cerned, it was an entirely new one; the maze was no longer the
same maze. The same criticism holds for the Higginson experi-
ment. Before conclusions regarding kinesthesis can be drawn,
an experimental device should be employed, in which the *general
geography* as well as other gross sensory features are kept con-
stant, and in which kinesthesis *only* is changed. The attempt to
do this led to the present study.

In the following experiments the rats were taught to run
through a maze in something like the ordinary fashion and then,
at various points in the learning process, were required to swim
through the same maze; or, reversing the situation, animals that
had learned to swim the maze were later required to run through
it. The assumption is made, that the kinesthetic stimuli received
in swimming from here to there, are materially different from
those received in running the same distance. The number of
locomotive movements of the extremities required in the one
case was approximately six times the number required in the
other. The body of a swimming rat is extended, while that of
the walking animal is, so to speak, gathered together; the mus-
cles called upon to counteract the effects of gravity face new
tasks. If kinesthesis, in any precise sense of the word, is the
essential factor in maze learning, there should be no transfer
from one of these situations to the other.

THE MAZE

The plan of the maze (see fig. 1) is in a sense a series of con-
densed T-mazes, each choice point presenting the true path and a
cul. For convenience the animals were led back to a point near
the starting box. The maze was constructed of redwood boards
1 inch by 12 inches, covered with No. 22 sheet tin so as to offer
an unscalable surface. The tin also reflected an image of the

Fig. 1.

animals, so that they could be observed while themselves undis-
turbed by sight of the observer. Each cul and each unit of the
true path measured fifteen inches in length.

Considerable care had to be used in the choice of width of
alleys. The four-inch alleys first used had to be changed to six-
inch alleys since the animals learned to "straddle," that is, to
support themselves by thrusting the rear legs against the sides,
and thus interrupted the smooth and continuous locomotion
which it was desired to establish. But in the six-inch alleys the
animals became stereotropic and followed the shore line, so that

the alley into which they turned was determined not so much by legitimate choice, as by the geography of the maze. Five-inch paths proved satisfactory.

The water tank into which the maze was placed was constructed of boards, covered with canvas, and painted to make it water-tight; dimensions 8 feet by 6 feet by 1 foot. When the rats were required to swim through the maze, the tank was filled to a level of eight inches. When walking was required, a false floor was placed in the maze alleys seven inches above the bottom of the tank. With the water at the same depth of eight inches, the false floor was covered with an inch of water. The visual and dimensional factors of the maze were, consequently, the same in the two situations.

At the point in alley 9 marked *x* in figure 1, a door was placed to prevent the animal's retracing of the first part of the maze after having passed the door.[3] This was essential since, otherwise, during the early runs the rats encountered so much difficulty in finding the food box, that they suffered from fatigue and from over-exposure to the cool water.

The reliability coefficients for the maze are given below. Two methods of calculating the coefficients were used: first, correlation of the odd-numbered runs against the even-numbered ones, and, second, correlation of the sum of the runs on the first half of the curve against the sum of the runs on the last half. In both cases the data for the first trial were not included. For groups I and II the figures from the first twelve runs were used; with groups V and VI, the curve was cut off at trial 17, since beyond this point a large number of zero scores occurred.[4]

RELIABILITY COEFFICIENTS

Group	Odd vs. even		Half vs. half
I	.470	(swimming)	.204
II	.445	(running)	.492
V	.727	(swimming)	.411
VI	.522	(running)	.375

[3] H. C. Blodgett has shown that the reliability of a maze is in no way diminished if doors are used in this way after *every* choice point.

[4] The data from groups III and IV could not be used since for these groups the conditions of traversing the maze were altered after only four trials.

THE EXPERIMENTAL ANIMALS

The animals used were albino rats. Males and females were taken indiscriminately except that they were about equally represented in each group. All rats were between sixty and sixty-five days of age at the beginning of each experiment. Each of the six groups consisted of approximately twenty animals. This number was sometimes reduced to nineteen and in one case to eighteen when one or more of them proved too weak to withstand the rigors of the first few runs.

TECHNIQUE

In each of the experiments the animals were given but one trial a day for the first two days of the training series. Longer exposure would have been inadvisable for those animals that began their training by swimming the maze. Thereafter all were given three trials per day, spaced by the time taken to run each of their eighteen or nineteen fellows.

During the first five trials, that is, the trials on the first, second, and third days, the temperature of the water was kept at approximately 74° F. Thereafter it was maintained at about 65° F.

For the animals that began their training by running the maze, arrangements were made as follows. In order that they might have some experience in deep water, no false floor was placed in alleys 1, 2, 3, and 4. In alley 5 an incline was so placed that, by the time the rat reached point Y (fig. 1), he was wading in but one inch of water and so continued to the food box.

The same arrangement was used for those animals that were required to run the maze after a practice period of swimming; since the animal was thus given an opportunity to get into its kinesthetic stride, interference would, presumably, be more pronounced when the change was introduced.

The animals were permitted to eat for a few seconds after reaching the dry landing box. In order to insure an approximately constant hunger drive, all animals were permitted to eat exactly twelve minutes a day aside from a few nibbles enjoyed at the end of each run. The water, particularly for the swimming animals, never ceased to be a source of persistent drive, although after the first few baths it caused no noticeable emotional disturbance.

Scoring points were arbitrarily determined as follows: the animal was considered to have entered either a cul or a section of the true path, if his progress took him into either to the extent of one body length exclusive of the tail. Only entrances into culs made while moving toward the goal were scored as errors; retracings were not so scored.

EXPERIMENTAL PROCEDURE AND DATA

GROUPS I AND II

In accordance with the plan to test the amount of transfer from one kinesthetic situation to another at various points in the learning process, groups I and II were changed from swimming to running and from running to swimming, respectively, just at that point where the learning curve began to flatten out.

GROUP I—

Group I (nineteen animals) was given twelve trials in swimming through the maze. Then the floors were put in place and two test trials were given. The last trial of the training series, trial 12, was given on the same day as the two test trials, in order that the swimming "set" might be at maximum.

COMPARISON OF ERRORS ON TRIALS 12 AND 13*

(See Chart 1)

Mean errors on trial 12, swimming........................... 1.26 σ .85
Mean errors on trial 13, running............................... 1.84 σ 1.22
Difference .... –.58 σ 1.23
Diff. /σ diff.. –.48
Odds favoring a real difference†...........................68 to 32

COMPARISON OF TIMES OF TRIALS 12 AND 13

(See Chart 2)

Mean time on trial 12, swimming........................... 26.42 σ 7.64
Mean time on trial 13, running............................... 76.57 σ 32.52
Difference .... –50.15 σ 30.32
Diff. /σ diff. 1.65
Odds favoring a difference.......................... 95 to 5

· These figures show that the slight rise in the number of errors in trial 13 over the number in trial 12, is of relatively little significance. Reference to the error curve will show that such difference as there is disappears on the fourteenth trial.

With regard to the time scores, however, a fairly reliable increase is obtained.[5] A reason for this rise suggests itself, and obtains in all cases in which the animals were practiced on swimming and tested on running. When the animal begins the test

----

* The formulae used in the computations are as follows:

$$\sigma \text{ distribution } = \sqrt{\frac{\Sigma x^2}{n} - \text{mean}^2}$$

$$r = \frac{\dfrac{\Sigma xy}{n} - M_x M_y}{\sigma x \, \sigma y}$$

$$\sigma \text{ diff.} = \sqrt{\sigma^2_x + \sigma^2_y - 2r\,\sigma_x\,\sigma_y}$$

See Kelley, T. L., *Statistical Method*, 182.

†This "odds favoring a real difference" is simply a translation of the critical ratio (diff./σ diff.) into terms of betting odds. Thus, on a basis of the supposititious normal frequency surface, if the same experiment with the same number of animals had been repeated 100 times, a difference as large as, or larger than, the one obtained and of the same sign would, according to pure chance, have occurred only 32 times out of the 100. The odds in favor of the found difference indicating a real difference of the given sign are, therefore, but 68 to 32.

[5] A comparison of the actual speeds of swimming and running throughout learning as shown on chart 13 indicates that the animal can swim the maze very nearly as rapidly as he can run it.

Group I

Chart 2

Group I

Chart 1
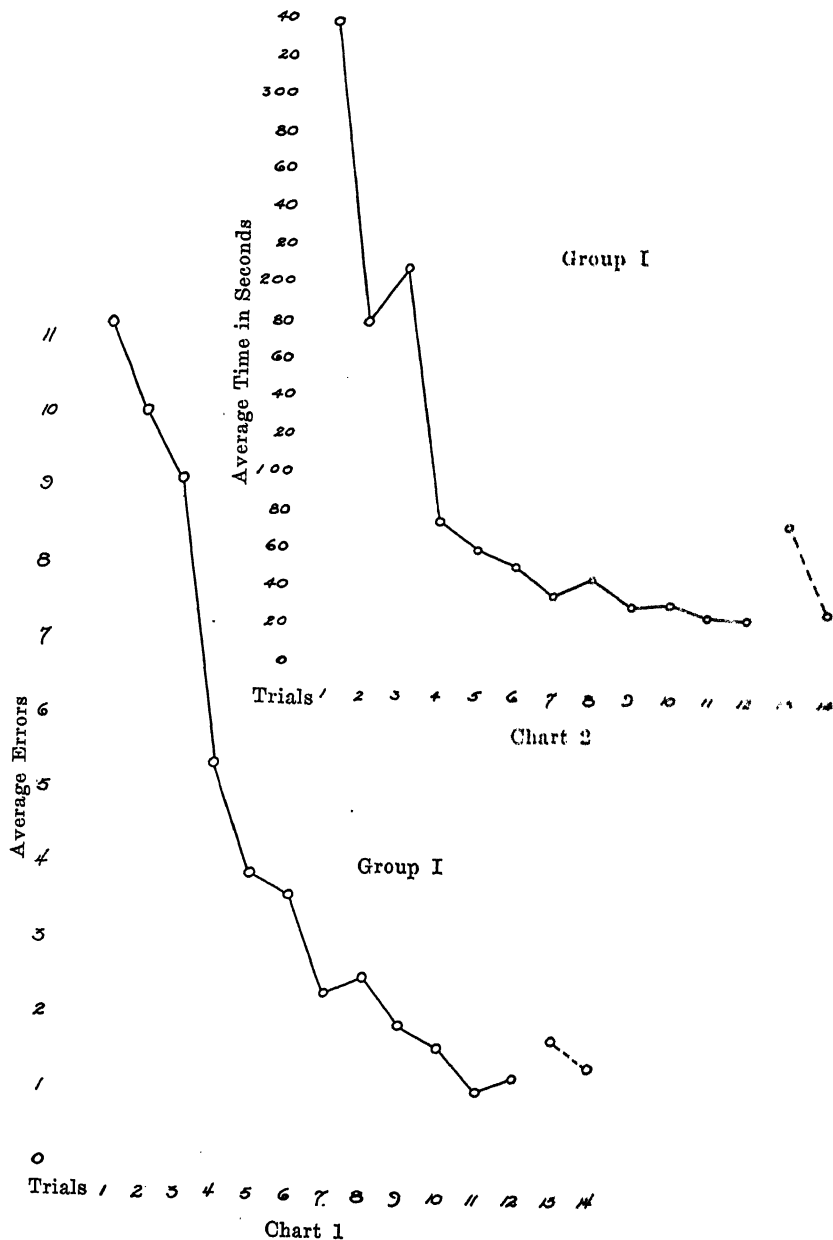
run and finds himself, at the end of alley 5, with a floor to stand on, he stands on it. This gives him an opportunity to inspect the features of the new situation, an opportunity of which all the animals availed themselves. They halted, sniffed, stood upright, tested the strength of the wire mesh above them and *then*—traveled down the correct alley. The entire run, for the most part, was made in this hesitant manner. This emphasizes the fact that, although a pronounced interference was produced as reflected in the change in time scores, it did not show itself to any appreciable extent in the number of errors made.

GROUP II—

With group II (19 animals) the situation that obtained in the case of group I was reversed. The rats were given twelve running trials; then the floors were removed and two test trials given.

COMPARISON OF ERRORS ON TRIALS 12 AND 13

(See Chart 3)

Mean errors on trial 12, running	1.15	σ	.86
Mean errors on trial 13, swimming	1.42	σ	1.04
Difference	.27	σ	1.18
Diff. /σ diff.	.23		
Odds favoring a real difference	59 to 41		

COMPARISON OF TIMES OF TRIALS 12 AND 13

(See Chart 4)

Mean time on trial 12, running	21.47	σ	12.16
Mean time on trial 13, swimming	23.31	σ	6.28
Difference	1.84	σ	11.97
Diff. /σ diff.	.15		
Odds favoring a real difference	56 to 44		

No significant difference is here found in either time or errors between trials 12 and 13. The animals, upon reaching the end of alley 5, found no floor to run upon, and had nothing else to do but carry on; consequently the times as well as the errors, failed to show a significant increase.

Chart 3

Chart 4
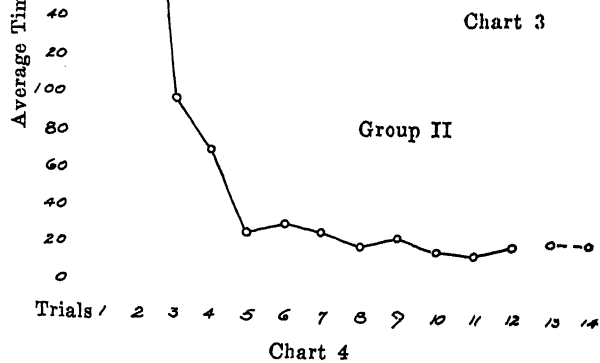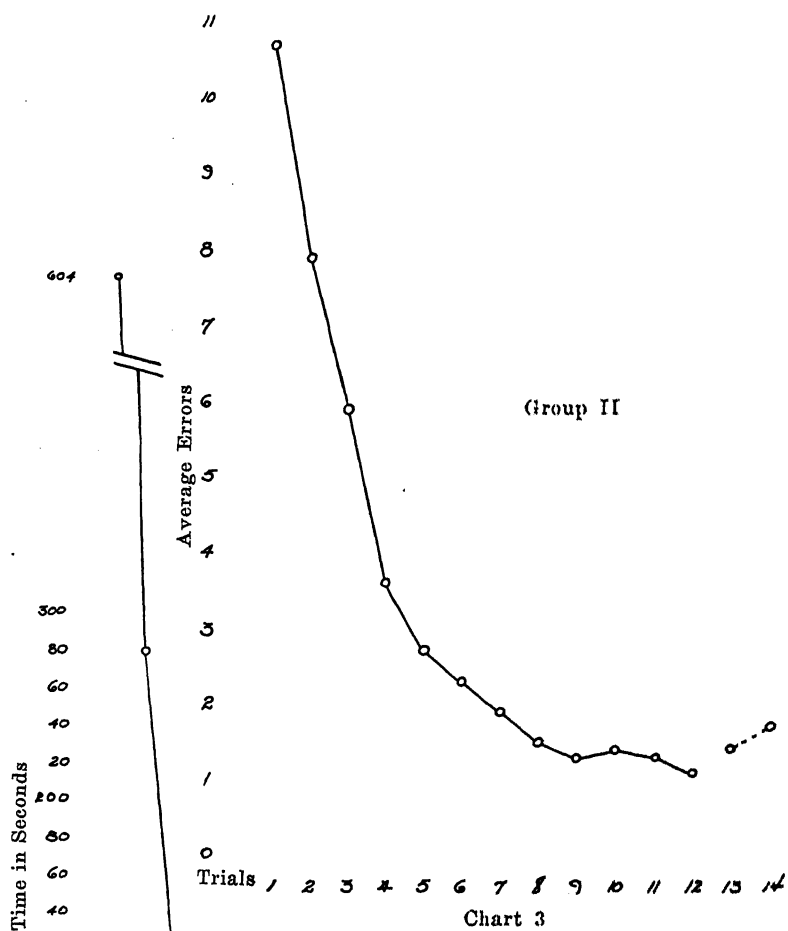
GROUPS III AND IV

It is probable that animals, in learning a maze, come first to condition their behavior to cues which, later, are discarded in favor of more potent ones. Although it seems unlikely that the stimuli used early in the process are kinesthetic, inasmuch as learning takes place to some extent before the locomotive patterns have become at all fixed, nevertheless, the following data permit a more definite answer to the question.

In groups III and IV the change from swimming to running and vice versa was introduced at a point about halfway down the steep part of the learning curve, between trials 4 and 5. If it can be shown, then, that the curves continue to drop in a manner comparable with that of a *normal* or *control* curve, it will appear probable that no integrations formed during the first four trials are wasted with reference to the new task.

GROUP III—

The twenty animals used in group III swam through the maze during trials 1, 2, 3, 4; from trials 5 to 12 inclusive, they ran. The animals of group V which swam the maze during the first twelve trials were used as a control group. If mere visual inspection of the error curves (see charts 5 and 9) for the two groups should not be deemed sufficient for purposes of comparison, reference can be made to the differences between various points and combinations of points along the two curves which are given in table 1.

From the above data and from inspection of the error curves, it is evident that the performance of group III may, to all intents and purposes, be adequately represented by the data and curve from the performance of group V.

GROUP IV—

The conditions imposed upon group III were reversed with group IV: the nineteen animals in this group ran for the first four trials and swam for the remaining eight. In spite of the

Group III

Average Time in Seconds

Trials *1   2   3   4   5   6   7   8   9   10   11   12*

Chart 6

Average Errors

Group III

Trials *1   2   3   4   5   6   7   8   9   10   11   12*
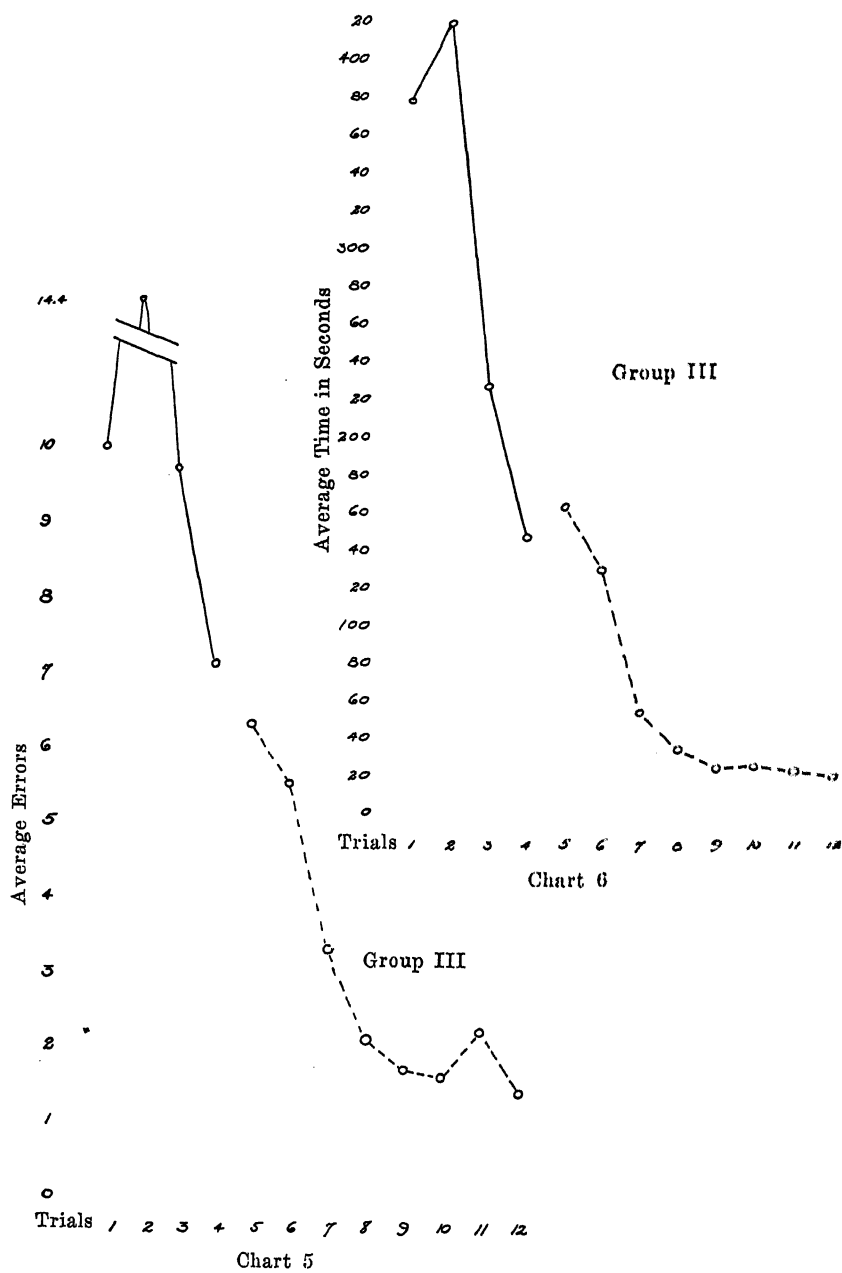
Chart 5

change in the mode of traversing the maze, the error curve is as smooth as could be expected (see chart 7) under normal conditions.

TABLE 1

COMPARISON BETWEEN GROUP III AND CONTROL GROUP V. COMPARISON OF
THE DIFFERENCES BETWEEN VARIOUS POINTS ON
THE TWO ERROR CURVES

Group	Compared points	Difference	Diff./σdiff.	Odds favoring diff.
III	3 and 4	2.45 σ 5.65	.43	67 to 33
V	3 and 4	2.16 σ 4.85	.45	67 to 33
III	4 and 5*	.80 σ 10.11	.08	53 to 47
V	4 and 5	1.22 σ 2.71	.45	67 to 33
III	5 and 6	.75 σ 2.37	.32	63 to 37
V	5 and 6	.56 σ 1.91	.29	61 to 39
III	3+4 and 5+6	4.95 σ 8.43	.58	72 to 28
V	3+4 and 5+6	5.6 σ 6.22	.85	79 to 21
III	3 and 6	4.15 σ 5.79	.72	76 to 24
V	3 and 6	3.94 σ 5.36	.74	77 to 23
III	2 and 7	11.10 σ 6.25	1.78	97 to 3
V	2 and 7	9.73 σ 5.25	1.86	97 to 3

*Here the change from swimming to running occurred.

As will be seen later, when group VI is discussed, the animals in that group ran the maze throughout the trials during which those in group IV first ran and then swam. Group VI may, then, be used as a control for group IV.

Table 2 presents the same sort of comparison between groups IV and VI that table 1 presents between groups III and V.

The similarity between the performances of group IV and group VI, though not so striking as that between the performances of groups III and V, still suggests that the record obtained for group IV would not have differed significantly had the change not been imposed.

Group IV

Average Errors

Average Time in Seconds

Trials   1   2   3   4   5   6   7   8   9   10   11   12

Chart 7

Group IV

Trials   1   2   3   4   5   6   7   8   9   10   11   12

Chart 8
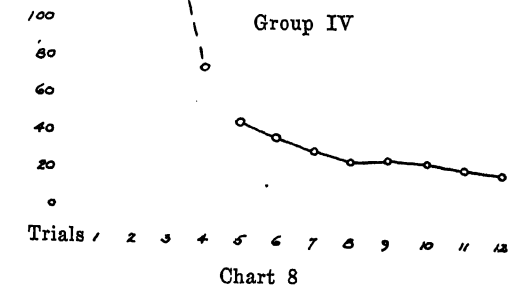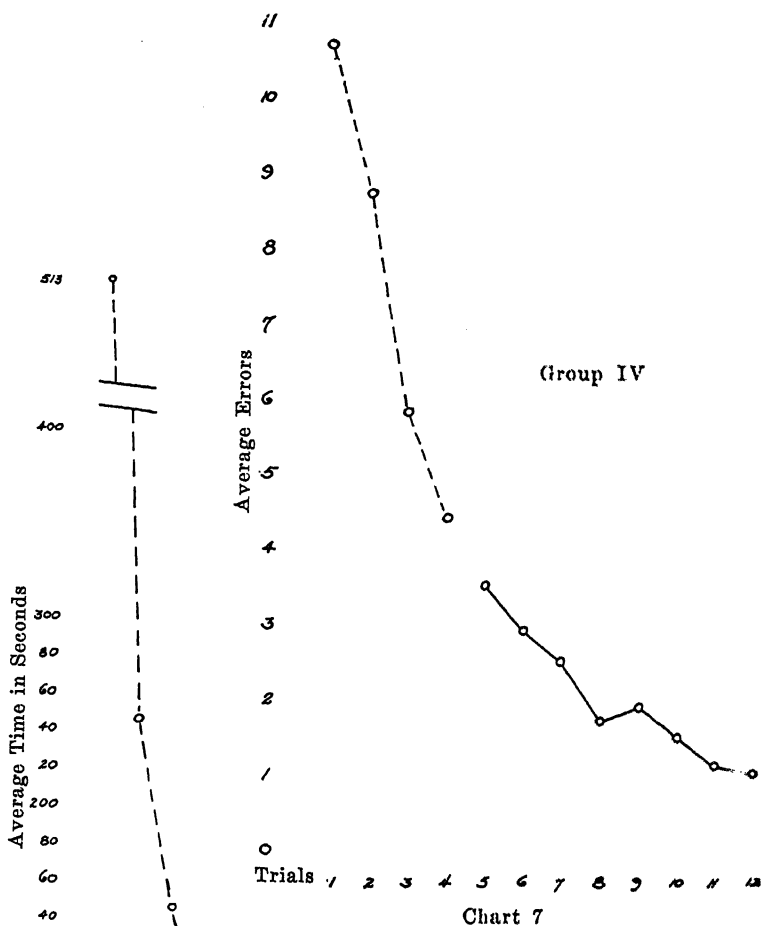
TABLE 2

COMPARISON BETWEEN GROUP IV AND CONTROL GROUP VI. COMPARISON OF
DIFFERENCES BETWEEN VARIOUS POINTS ON
THE TWO ERROR CURVES

Group	Compared points	Differences	Diff./σ diff.	Odds favoring diff.
IV	3 and 4	1.38 σ 3.35	.41	66 to 33
VI	3 and 4	2.0 σ 2.37	.84	80 to 20
IV	4 and 5*	1.00 σ 1.70	.59	72 to 28
VI	4 and 5	.65 σ 1.72	.38	65 to 35
IV	5 and 6	.53 σ 1.46	.36	64 to 36
VI	5 and 6	.85 σ 1.04	.82	79 to 21
IV	3+4 and 5+6	4.21 σ 4.50	.93	82 to 18
VI	3+4 and 5+6	4.15 σ 3.24	1.28	90 to 10
IV	3 and 6	2.90 σ 2.99	.97	83 to 17
VI	3 and 6	3.55 σ 2.32	1.53	94 to 6
IV	2 and 7	6.21 σ 3.79	1.64	95 to 5
VI	2 and 7	7.0 σ 3.02	2.31	99 to 1

*Where the change from running to swimming occurred.

GROUPS V AND VI

It seems certain from the results presented thus far that
during the early stages of learning the rat depends primarily on
exteroceptive sense data. Does he continue to respond to these
same exteroceptive cues when the performance has become rela-
tively automatic or does he shift to kinesthetic cues? And if a
change is now made from swimming to running or vice versa,
will there be more of an upset? Is it possible that, although
kinesthesis is not essentially involved in the early part of learn-
ing, i.e., in determining *what* is done, nevertheless it is involved
in the later part of learning, i.e., in determining *how* it shall be
done?

The rats in groups V and VI were made to overlearn the maze before the change was introduced.

GROUP V—

Group V reached on the seventeenth run what proved to be, in terms of errors, the plateau point. Practice was continued for approximately twice this period—out to the thirty-third run.[6] In terms of the time scores, practice was continued to about three times the amount required barely to learn the maze.

The eighteen animals used in this group swam during the first thirty-three trials and ran four test trials.

<div align="center">

COMPARISON OF ERRORS OF TRIALS 33 AND 34

(See Chart 9)

</div>

Mean errors on trial 33, swimming	.2	σ	.4
Mean errors on trial 34, running	2.05	σ	2.05
Difference	1.85	σ	1.94
Diff./σ diff.	.95		
Odds favoring a difference	83 to 17		-

This increase of 1.85 errors on the first test trial may be viewed in a number of ways, particularly if the entire learning curve for group V is scrutinized. The fact that, on test trials 2, 3, and 4, the curve falls back to a level, nearly as low as the plateau level, suggests that the upset produced by the change is of an emotional nature, rather than indicative of a lack of knowledge of the maze as a whole. In the second place, the animals were unevenly affected by the change; one of the animals made zero errors both on trials 33 and 34, five increased their errors by but one, while still others made four, or even five errors on trial 34.

The point to which the error curve falls on the second, third, and fourth test trials is approximately that attained on the fourteenth training trial, and it seems probable that this represents the point at which all but the most refined adjustments involved in the learning, have been acquired.

The time scores on the test trials rose about an equal amount.

---

[6] Trial 33, the last one of the training series, was the first trial of the day upon which the tests were given. All four of the test trials were given on the same day.

Chart 9

Group V

Average Errors
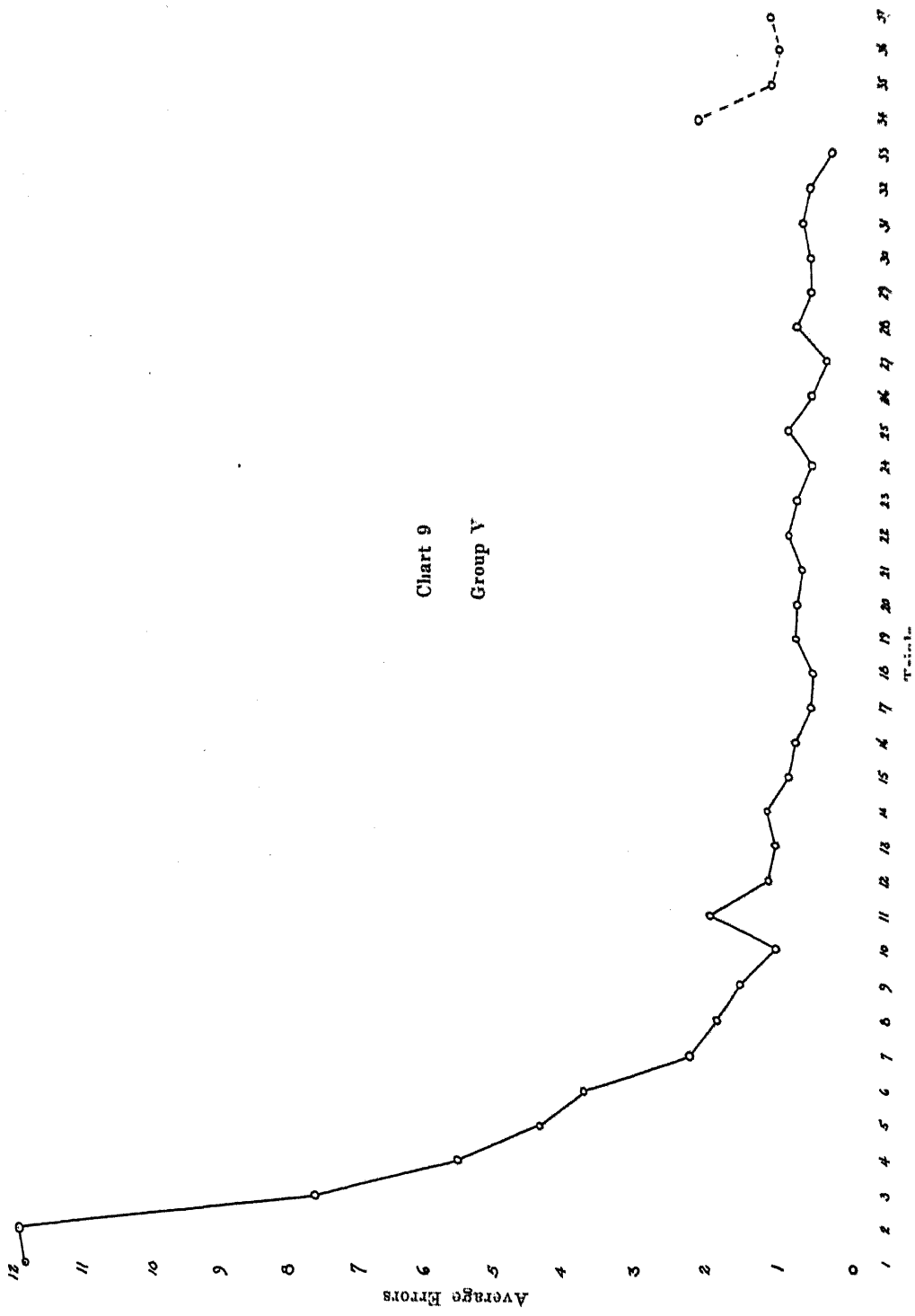
Trials

COMPARISON OF TIMES OF TRIALS 33 AND 34

(See Chart 10)

Mean time on trial 33, swimming........................ 18.38　　σ　　7.68
Mean time on trial 34, running............................. 51.72　　σ　　23.70
Difference .... 33.34　　σ　　22.76
Diff. /σ diff. 1.46
Odds favoring a difference...................................93 to 7

GROUP VI—

The conditions which obtained in the case of group V were reversed with group VI. The twenty animals in the group ran the maze for thirty-three trials and swam for four test trials. An inspection of the error and time curves will show that the amount of overlearning is practically the same as for group V.

COMPARISON OF ERRORS ON TRIALS 33 AND 34

(See Chart 11)

Mean errors on trial 33, running..................... .3　　σ　　.56
Mean errors on trial 34, swimming. .... 1.05　　σ　　1.03
Difference .... .75　　σ　　1.04
Diff. /σ diff. .... .72
Odds favoring a difference.............................76 to 24

The animals of group VI reflected in their error record the effect of the change less than did those of group V. The disturbance, represented by an increase of .75 errors per rat, entirely disappeared on the third and fourth test trials, suggesting again, that the upset was probably an emotional one. It is of interest to note at this point that, if that part of the error curve which represents the test trials is moved over to the left, it fits without a break at about trial 14. If we consider that the trials after trial 14 bring about simply increased skill and habituation, it is clear that no essential knowledge of the maze as a whole has been lost as a result of the change in the conditions of running. From the records of the individual animals we find that, on the first test trial, nine of the twenty animals made as few or fewer errors than they made on the last trial before the change.

Chart 10

Group V

Average Time in Seconds
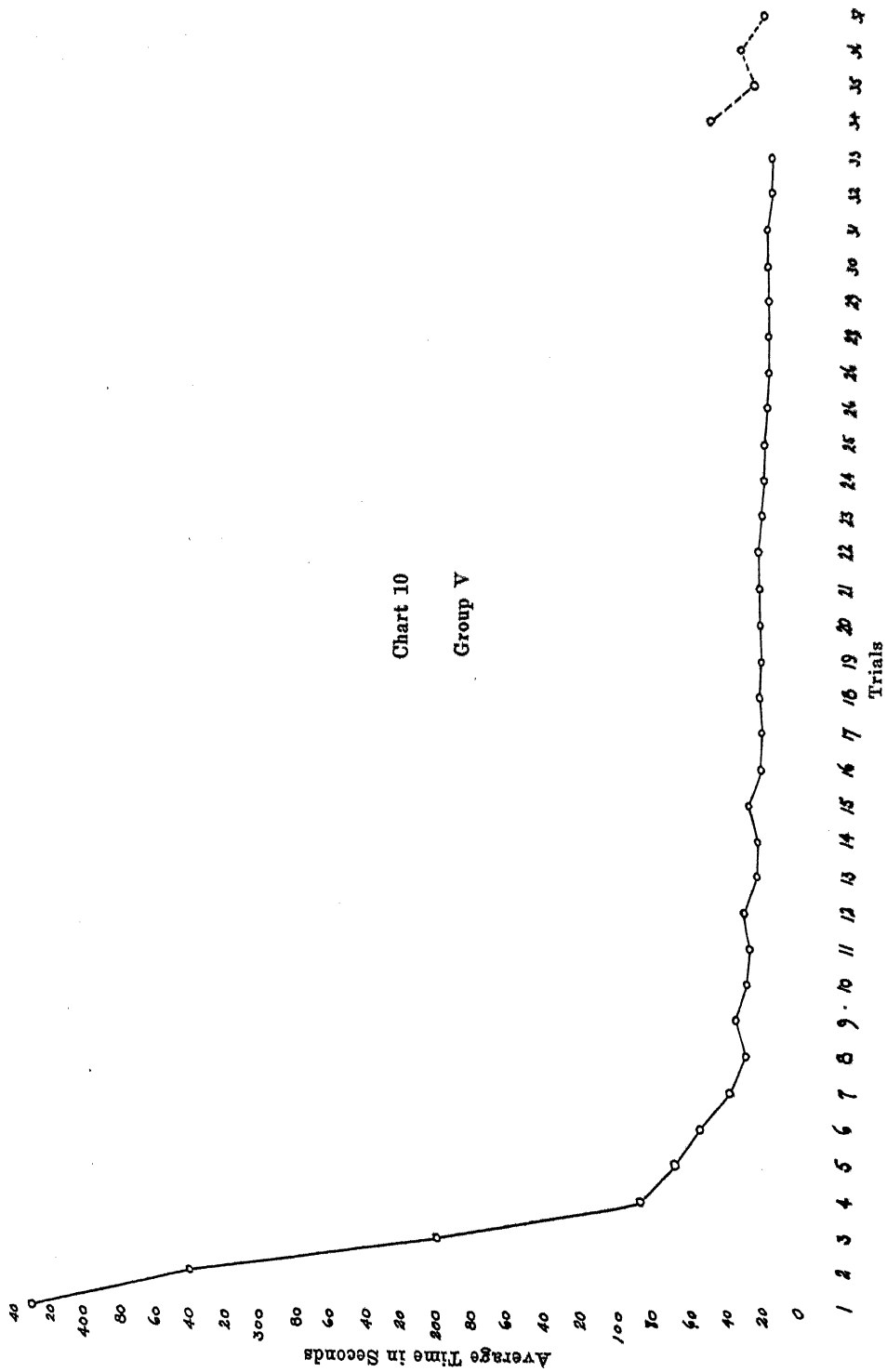
Trials

The increase of the time score of trial 34 over trial 33 is practically nothing more than the increase of swimming time over running time (see Chart 13).

COMPARISON OF TIMES OF TRIALS 33 AND 34

(See Chart 12)

Mean time on trial 33, running............................... 11.85	σ	1.46
Mean time on trial 34, swimming........................... 23.60	σ	10.24
Difference ....−11.75	σ	9.62
Diff. /σ diff. 1.22		
Odds favoring a difference....................................89 to 11		

SUMMARY OF THE DATA

GROUP I. SWIMMING TO RUNNING, CHANGED ON TRIAL 13

In terms of errors the animals of Group I were but slightly disturbed by the change to running; there was an average increase of half an error per rat, and this difference had but slight statistical reliability. The time scores for this group rose markedly, from an average of 26 seconds to one of 76 seconds, per run. .

GROUP II. RUNNING TO SWIMMING. CHANGED ON TRIAL 13

The animals in group II were less disturbed than those in group I. An unreliable increase of .27 errors per rat was obtained. Some account must be taken with this group, as with all the groups where the change was from running to swimming, of the increased drive furnished by the deep water. While it cannot be said with certainty that this pressure per se kept the errors down, it is safe to say that it did keep the time scores from rising. With group II no significant change occurred in the time scores.

Chart 11

Group VI

Average Errors

Trials

Chart 12

Group VI

erratic rest

Average Time in Seconds

Trials

600
400
300
200
80
60
40
20
100
80
60
40
20
0

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37

Group V. Swimming

Group VI. Running
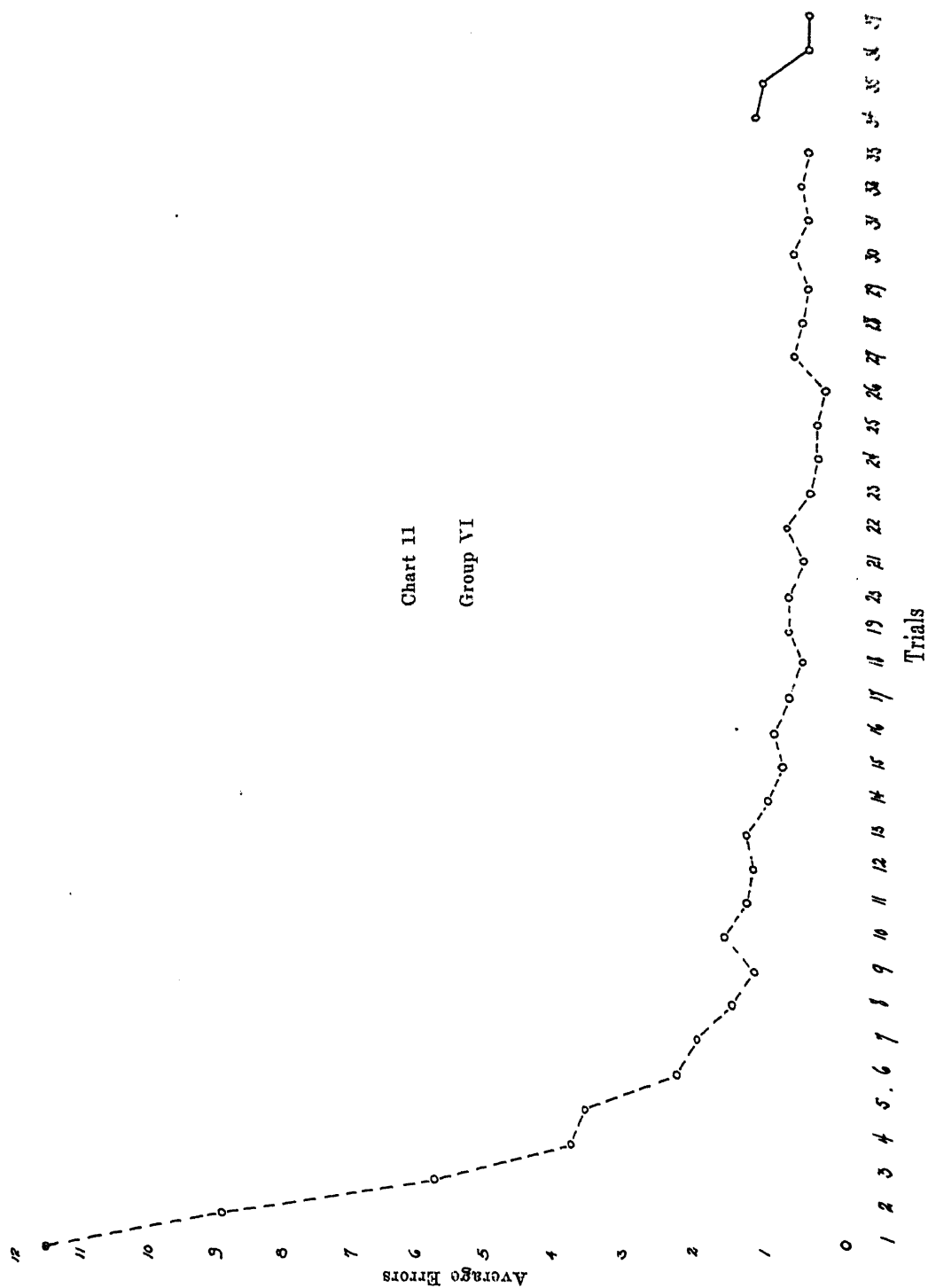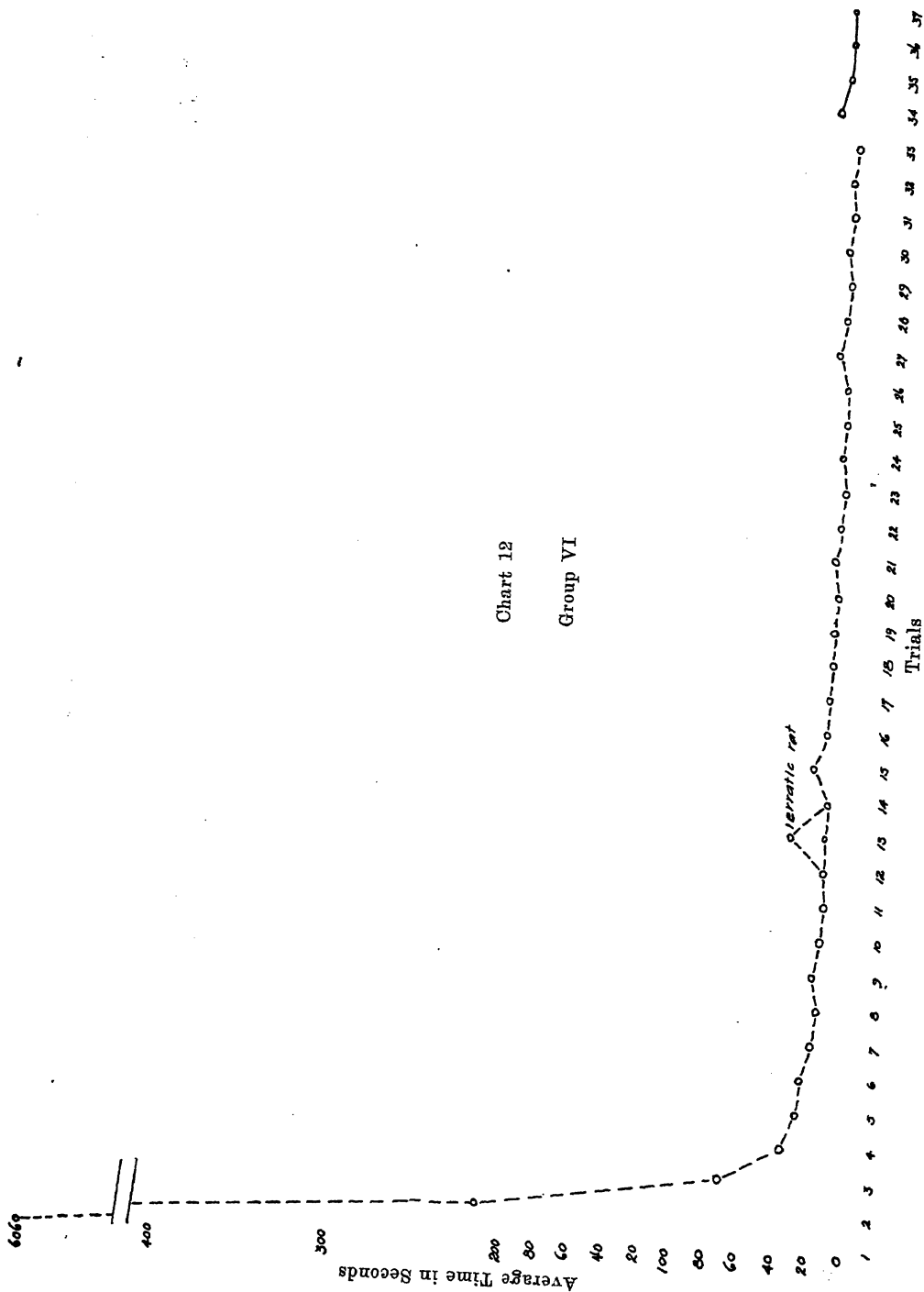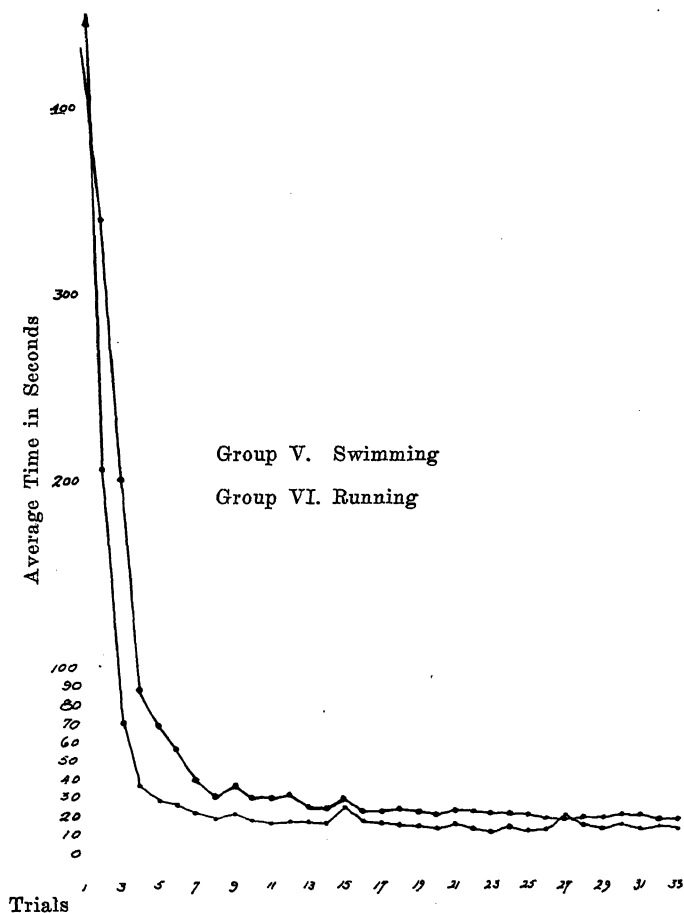
Chart 13

GROUPS III AND IV. CHANGED ON TRIAL 5

The performance of groups III and IV, with which the change was introduced during the rapid drop of the learning curve, was practically indistinguishable from the performance of control groups, except that the time score for the group that shifted from swimming to running increased slightly.

Group V. Swimming to Running. Changed on Trial 34

The rats in the fifth group, which had been to a considerable extent overtrained, showed on the first test trial a small, but reliable disturbance. The animals made, on the average, two errors on this test trial, an increase of 1.85 errors per rat. This increase dropped on the following trial to .88 errors per rat. It is to be noted that most of the errors recorded for this trial were made by one animal. The time scores for these animals rose on the first trial from 18.38 seconds to 51.72 seconds and then rapidly dropped again.

Group VI. Running to Swimming. Changed on Trial 34

The performance of group VI was similar to that of group V except that the increase in the error scores at the time of the change was less marked. An increase of three-fourths of an error per rat was obtained on trial 34 over trial 33; on trial 35 the errors had decreased again, and on trials 36 and 37 the curve had dropped as low as the plateau level of the overlearning period. The increase in time scores was almost negligible.

CONCLUSIONS

If it were true, in accordance with the tradition of Watson and Carr, that animals are pushed through the maze by a succession of precise kinesthetic stimuli, the complications encountered in the present experiments would have rendered the learning acquired during the earlier trials of little or no avail on the test runs. Yet, barring the effect of emotional disturbance, the altering of the proprioceptive cues had little effect on the error scores of the animals. The fact that the time scores rose significantly with the animals that were changed from swimming to running, only emphasizes this outcome.

It may be objected that, in the present experiments, one source of kinesthetic stimulation remained constant and unaffected by the changes from swimming to running and vice versa. May it not be that the animals, in learning the maze, learn, not to condition their behavior on the entire complex of muscular sensations, but to respond simply to a succession of head movements? The organic stimuli from such movements would, it is true, be generally the same whether the rat were swimming or running. And such movements can be observed, particularly while the animals are swimming: they do not travel straight down the middle of an alley but anticipate the corners by a diagonal approach. Such anticipatory movements, made before the choice point is reached, could not, however, furnish information regarding which of the two alternatives was the true path. But suppose they could. Hunter, using his temporal maze, was unable to show that the rats could learn a pattern of turns *as such*, divorced from concomitant spatial characteristics, even when the pattern was as simple as that indicated by the formula *rrllrrll*. The criticism made above implies that the rats can learn a sequence of turns represented, in the case of our maze, by the formula *rlrrlrlrll*—which is improbable. This in turn suggests that the spatial characteristics of a maze may, after all, be the crucial ones. Concerning the channels through which the rat perceives these characteristics, we can at present only speculate, but this exciting field should be further investigated.

The results of these experiments suggest that a distinction should be made between those elements of learning acquired by the animal whereby he is able to make proper adjustments to the maze as a thing to be got through—as a complete situation envisaged as a whole, and those other elements which tell him in just what manner the perceived end is to be accomplished. It is one thing to discover or, speaking more psychologically, to learn that an objective we seek is on the opposite side of a river, and quite another to acquire the skill to swim to it. The architect who knows how a house should be built, would prob-

ably split his thumb nail if he invaded the province of the car-
penter. Similarly, it would seem to be with the rat in the maze.
Our animals were in no doubt as to the location of their dinner,
although they were prevented from using their customary means
of getting it. This analogy may be thrown out in view of the
rapid recovery of adjustment after the enforced change of re-
sponse, and the ''skills'' involved in maze running may be con-
sidered as quite apart from other precise neuromuscular abilities,
such as those employed in playing the piano or sawing a board.
On the other hand, these ''skills'' may be thought of as having
been acquired or possessed by the animal previous to the experi-
ment, possibly as a part of his original equipment, and utilized
later as the occasion demanded.

These facts, however, we have : first, that the changes in kines-
thesis brought about by the conditions of these experiments had
but slight effect on the ability of the animals to traverse the maze
without entrances into culs-de-sac, and, second, that such dis-
turbances as there were, rapidly disappeared. We may speculate
concerning the part played by kinesthesis in determining *how*
the food box shall be reached, but we may safely deny it the
power to tell the rat *where* he shall go to reach it.

278
27

LITERATURE CITED

1 BLODGETT, H. C.
    1929. The Effect of the Introduction of Reward upon the Maze
        Performance of Rats. *Univ. of Calif. Publ. Psychol.*, 4:
        113–134.

2 CARR, H.
    1914. Principles of Selection in Animal Learning. *Psychol Rev.*,
        21:157–165.

3 CARR, H.
    1917. Maze Studies with the White Rat. *Jour Anim. Behav.*, 7:
        295–306.

4 CARR, H., and WATSON, J. B.
    1908. Orientation in the White Rat. *Jour. of Comp. Neur. and
        Psychol.*, 18:27–44.

5 HIGGINSON, G. D.
    1926. Visual Perception in the White Rat. *Jour. Exp. Psychol.*,
        9:337–347.

6 HUNTER, W. S.
    1918. Kinaesthetic Sensory Processes in the White Rat. *Psychol.
        Bull.*, 15:36–37.

7 HUNTER, W. S.
    1920. The Temporal Maze and Kinaesthetic Sensory Processes in
        the White Rat. *Psychobiol.*, 2:1–18.

8 LASHLEY, K. S.
    1921. Studies of Cerebral Function in Learning. III. The Motor
        Areas. *Brain*, 44:255–285.

9 LASHLEY, K. S., and McCARTHY, D. A.
    1926. The Survival of the Maze Habit after Cerebellar Injuries.
        Jour. Comp. Psychol., 6:423–434.

10 WATSON, J. B.
    1907. Kinaesthetic and Organic Sensations: Their Rôle in the Reac-
        tions of the White Rat to the Maze. *Psychol. Rev.
        Monogr. Suppl.*, 8, No. 2:100.

DELAYED REACTION IN RATS

BY

C. H. HONZIK

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—Warner Brown, Harold E. Jones, and Edward C. Tolman, Editors.

Price per volume, $3.50.

DELAYED REACTION IN RATS*

BY

C. H. HONZIK

INTRODUCTION

W. S. Hunter,[1] in 1913–14, working on delayed reaction in animals and children, found that rats could not delay successfully unless they oriented their bodies toward the spot from which they received the stimulus and kept this gross bodily orientation throughout the delay. In his set-up for the rats Hunter used a three-door choice box with an electric light globe behind each door. The correct choice was always the door where the light was burning, and in the delayed reaction trials the light was turned off from one to ten seconds before the rat's release. In Hunter's own words:

> The rat, when put into the release box during the delayed reactions, oriented immediately to the light with its entire body and began a series of attacks on that side of the box in an effort to get out. This attempt was kept up until the animal was released, whereupon it went to the box (that is, the door) straight in front. Experiment served only to lengthen the period during which they would attack any one side of the release box. These statements hold true for all rats.

Maier,[2] in 1929, used a set-up that consisted of three ring-stands, from the top of which elevated paths led to a table and food, but only one ringstand (and its path) led to food; the other two did not. The rat was first placed at the bottom of the correct ring stand and allowed to run up it and over the path to

---

food three times in succession. The rat was then delayed on the table or in another room for varying periods of time, from 1 minute to 24 hours, and finally allowed to descend from the table by a fourth ringstand and to attempt to choose, while on the floor, that ringstand and path over which he had run previously, this being the correct route to food. Maier's results showed that the rats could often delay successfully over long periods of time. Maier stresses the point that the associative values of a stimulus, that is, the distinctiveness and familiarity of the environment in which the stimulus is set, constitute an important factor for such delayed responses. He thinks that Hunter's rats could not delay successfully (without gross bodily orientation) because the three doors from which they were to choose the correct one were not, as such, sufficiently differentiated from one another.

It occurred to the present writer that perhaps rats could delay successfully even in a choice box similar to Hunter's, if, before the delay, they were allowed to run up to the stimulus. The emphasis was thus put upon this preliminary *running toward* the stimulus. And this, it seemed, would have two advantages: (1) it could be made certain that the rat had actually received the stimulus, and (2) this running toward the stimulus would probably also reinforce the stimulus and hence enhance the animal's ability, after the delay, to react correctly to the place where it had been. Preliminary to the delayed reaction trials, it was of course necessary to train the rats to react correctly and unhesitatingly to some definite stimulus. For this stimulus a white cloth curtain was used in conjunction with two black curtains. The preliminary training was thus one of simple discrimination. The rats were required to learn to choose the door that held the white curtain. The position of this white-curtained door was varied irregularly among the three possibilities on successive trials.

APPARATUS AND METHODS

The apparatus is shown diagrammatically in figure 1. The discrimination box was made of ¾″ redwood with dimensions as shown. To make the three doors visible to the reader, two sides of the box have been omitted in the figure. The curtains were fitted on the outside of the box and hung half an inch below the lower edges of the doors so that the path leading from the door to the food box could be seen only by pushing aside the curtain.
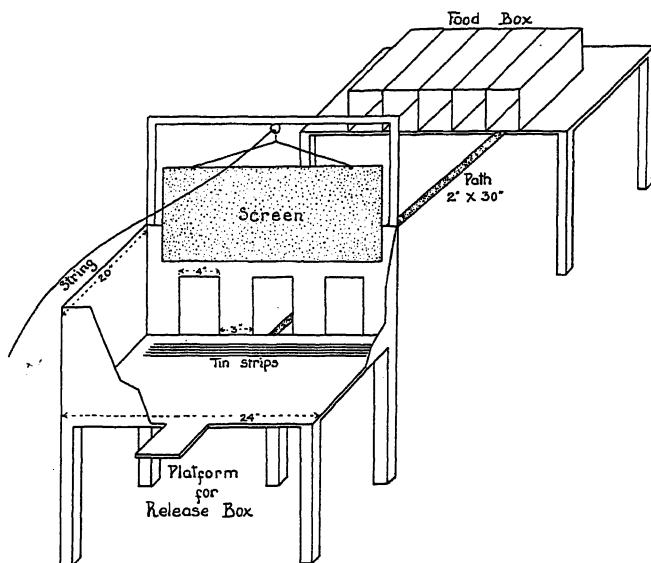
Fig. 1

Two of the curtains were black, the third white, and the white curtain was shifted haphazardly from door to door on successive runs. A starting box fitted with a sliding door, and set on the platform indicated in the figure, was used to release the rats into the discrimination box. Just in front of the doors five narrow strips of tin were tacked to the floor of the box; these were connected to one pole of a small transformer. On the very edges of the doors, short lengths of copper wire were fastened, and

these were connected to the other pole of the transformer. By throwing in the proper switches, the two wrong doors, that is, the two with black curtains, could be electrified, so that a rat with hind feet on the tin strips, seeking to poke his nose under a black curtain would invariably receive a slight shock. It was found that the electric current had to be stepped down considerably below the human threshold, rats being apparently much more sensitive to electric shocks than humans. This punishment for wrong responses tended to speed up the preliminary discrimination learning.

The rats.—The rats used in the experiment were all male albinos, ranging in age from three to six months. During the training they were fed one to two grams of Steenbock mash after each run, and at the end of the day's running a slightly larger amount was given. This was sufficient to keep the rats hungry and eager for food during the entire day's running and throughout the training period.

Preliminary training.—In order to accustom the rats to the box, elevated path, and curtains, preliminary training was given as follows: first day, six runs to food on the elevated path alone; second day, six runs through the discrimination box and over the elevated path, no curtains being used; third day, same as second; fourth and fifth days, nine runs each day with the curtains raised at first two inches above the lower edges of the doors and lowered gradually on successive runs until they hung below the edges of the doors.

RESULTS OF DISCRIMINATION TRAINING

Beginning with the sixth day, discrimination proper was begun. The correct door, that is, the door which had the path leading to food, always held the white curtain. Punishment of errors took the form of the electric shock as earlier described. The number of runs each day varied from nine to thirteen. A correct run was one in which the rat did not try to get out through a black-curtained door; the slightest movement of a

black curtain by the rat was considered an error even though the rat did not push the curtain far enough to see that no path was at that door. The white curtain was never at the same door two runs in succession.

Two groups of rats, one containing eleven rats, the other eight, were given 12 and 9 days of such discrimination training, respectively. Table 1 gives the figures for the total runs and for the correct runs.

TABLE 1

RESULTS OF DISCRIMINATION TRAINING

Rats	Days of running	Total number of runs	Number of correct runs
W1...	12	124	104
W2....	12	124	107
W3...	12	124	109
W4..	12	124	101
W5....	12	124	108
W6. ...	12	124	108
W7.	12	124	103
W8...	12	124	102
W9....	12	124	104
W10...	12	124	105
W11....	12	124	106
W13....	9	93	83
W14...	9	93	89
W15...	9	93	91
W16....	9	93	84
W17...	9	93	84
W18....	9	93	78
W19...	9	93	86
W21..	9	93	90

The rapidity of the rat's learning was indicated by the fact that practically all the errors were made during the first three or four days; after the fourth day only a few errors were made, and 7 of the 19 rats made none. Most of the rats learned to run straight toward the white door the instant they were released; a few would occasionally run toward a black door, pause an instant, and then turn to the white door.

RESULTS OF DELAYED REACTION

When the discrimination of the white door was well learned, delayed reaction runs were started. These were conducted as follows: The white curtain was fastened to the front of a block of wood of the same size as the curtain itself. To the lower edge of the block a black curtain was fastened so that by raising the block and its white curtain by means of a string the black curtain could be brought snugly into place, making the door appear like the other two black doors. The rat was allowed to run toward the white curtain, but the wooden block behind it prevented further progress. As soon as the rat had reached the white curtain, the screen (see fig. 1) was lowered, and the rat was delayed for varying lengths of time during which time the rat did not stay in any one position but invariably ran about in the box. Meanwhile the block holding the white curtain was raised, bringing the black curtain into position so that when, after the delay, the screen was raised the rat was confronted with three black doors, and his task then was to choose the door at which the white curtain had been a few seconds previously.

For the first three days of the delayed reaction training such delayed runs were interspersed among the ordinary discrimination runs. Only about five or six runs on each of these three days were delayed reaction runs. The object of this was to disturb as little as possible the rats' habit of taking the white door. It was thought that an abrupt and complete change to the delayed reaction situation would tend to confuse the rats and disrupt their habit of running invariably toward the white curtain. After the third day all rats had 12 runs daily and of these the first, fifth, and ninth were discrimination runs; thus after the third day there were, each day, nine delayed runs and three discrimination runs.

During the first four days of this delayed reaction training the electric shock was not used; it was resorted to later only

with those rats that were slow in learning which of the three black doors was correct.

As in the previous discrimination training an error consisted of moving, however slightly, a curtain in any of the two wrong doors.

Table 2 gives the results of the choices after the delays.

TABLE 2

RESULTS OF DELAYED REACTION

Rats	Total number of runs	Number of correct runs	Per cent of correct runs
W1	238	150	63
W2	238	179	75
W3	114	38	33
W4	238	187	78
W5	238	192	81
W6	114	45	39
W7	81	23	28
W8	81	27	33
W9	211	153	72
W10	211	181	86
W11	211	190	90
W13	88	74	84
W14	88	76	86
W15	88	68	77
W16	88	70	80
W17	88	75	85
W18	88	57	65
W19	88	70	79
W21	88	83	94

Since there were three doors in the box to choose from, the probability of choosing the correct door in any one run *by chance alone* would be one-third; and in a large number of runs the most probable number of correct runs by chance would be one-third of the total number of runs. Thus, for example, rat W1, who had a total of 238 runs, could have 33 per cent, or 79, of these correct by chance alone. Actually he had 63 per cent correct, or almost double his chance percentage. It will be seen

from table 2 that, of the nineteen rats, only four (W3, W6, W7, and W8) had actual percentages close to the percentage expected by chance. The remaining fifteen rats had actual percentages ranging from 63 to 94, that is, from double to almost treble the chance percentage.

It is reasonable to assume that if a rat has at least twice as many correct runs as chance alone would give him, he was not choosing doors haphazardly, but he was either in some sense able to remember the door that had had a white curtain some time previously or he was being guided by some cues, e.g., olfactory, auditory, tactual, or visual, that were not noticed by the experimenter.

To rule out possible visual or auditory cues the following precautions were taken: (1) the black curtains were made not only of the same entirely opaque material but were shifted about from door to door so that no curtain which might have had some distinctive mark not visible to the experimenter, could serve as a guide; (2) all curtains were always closely fitted and hung below the lower edge of the doors, thus preventing vision of the path; (3) in addition to the string by which the wooden block was raised, two false strings leading to the other two doors were used; (4) the slight scraping sound made by raising the wooden block was precluded as a guide by fixing weights to the two false strings and raising these on each run; (5) the movements of the experimenter, which might have acted as guides, were not visible to the rat.

To rule out a possible olfactory cue several checks were made: (1) the black curtain which was fastened to the lower edge of the wooden block and which was always the correct curtain and therefore presumably more "smelled-up" than the other curtains, was frequently used in the other doors; (2) the two-inch wooden path, which might possibly be smelled through the curtain, was replaced by entirely new paths made of fresh lumber, and the old path was placed behind a wrong door so that, if the rats were smelling the path through the curtain, they would

tend to take the wrong door leading to the old path; (3) three pieces of cardboard eight inches square were placed on the floor of the box in front of the doors and these were shifted about while the rat was being delayed in the box, in this way eliminating a possible dependence on the scent track the rat might have made when he originally ran toward the white curtain.

Each of these checks for some possible guiding cue was made with at least eighteen runs. *No* disturbances were observed in any case in the rats' choices of the correct door.

LENGTH OF DELAY

Both groups of rats were started on their delayed reaction runs with delays of 7 seconds, the time required to raise the wooden block and to fasten the string at the proper place. The first group of rats (those numbered from 1 to 11), which were given over 200 delayed runs, had the delay period lengthened first to 15 seconds (45 runs), then to 30 seconds (an average of 40 runs), and finally to 45 seconds (30 runs). With the longer delay periods the behavior of the rats became somewhat uncertain, there was a noticeable hesitancy in the choice of the correct door, but in general the correct choices with longer periods of delay were no less frequent than with the preceding short periods. A delay period of 3 minutes was tried with the rats of the second group with 4 runs per rat, and the number of correct responses was somewhat higher than would be expected by chance, but since the runs were so few in number the result is somewhat doubtful.

FURTHER RESULTS OF DELAYED REACTION

To make the changing of curtains during the delayed reaction procedure easier and more rapid, the following changes in apparatus were made. A quarter-inch board of sufficient size to cover at once all the three doors was covered with the same

black cloth of which the curtains were made. This cloth-covered board then served for the black curtains, except for a smaller white piece of cloth which could be tacked over the black cloth at any desired position, thus making the door at that position the white door. To the lower edge of the board three black curtains were fastened, so that the raising of the board with its black and white cloths brought at once all three lower black curtains into position before the doors.

With this arrangement two more groups of rats, containing respectively 6 and 9 male albino rats, were run, using a 7-second delay period. Table 3 gives the results of the delayed reaction runs for these groups.

TABLE 3

RESULTS OF DELAYED REACTION

Rats	Total number of runs	Number of correct runs	Per cent of correct runs
W22	127	103	81
W23	127	55	43
W24	127	66	52
W25	127	81	63
W26	127	115	90
W27	127	114	90
W28	104	55	53
W29	104	66	63
W30	67	26	39
W31	67	22	33
W32	104	68	65
W33	104	51	49
W34	104	86	83
W35	104	74	71
W36	67	34	51

It will be noticed that in these two groups of 15 rats, 8 rats have percentages of correct runs at least twice as large as would be expected by chance, and that there are two percentages as high as 90. Four rats (W24, W28, W33, and W36) have the following percentages, 52, 53, 49, and 51, respectively, which

would indicate that these rats were able sometimes to remember the position of the white curtain, but not consistently. Three rats (W23, W30, and W31), as their percentages show, were completely unable to remember the white curtain and chose the black doors haphazardly. The behavior of these three rats in the box, when the choice of a door was to be made, was distinctly different from that of the rats whose percentage for correct runs was high. The better rats would often pause before a curtain or before two curtains in succession before finally choosing the correct one, the poor rats would undiscriminatingly poke their noses under the nearest curtain and very often return to a curtain that they had already tried.

A repetition of the experiment made by a graduate student confirmed the previous observation of the writer that in the administering of electric shock for wrong responses great care must be taken, and that the rats are easily ruined for further running by too heavy and persistent shocking. It was found in this repetition of the experiment that most of the rats would not attempt any door (in the delayed reaction runs) when three black doors were presented, and that the rats that did try the doors did so only with evidences of great fear and reluctance. With this in mind the present experimenter ran a fourth group of ten rats under the same conditions existing with the second and third groups with the exception that during the preliminary, i.e., the discrimination, training, 51 runs were given in which all three doors were black but no shock was used. Thus the rats were trained to take the white door when it was present but also to attempt one black door after another when all were black. When the delayed reaction training was started, five of the most active and least fearful rats were selected and given 100 delayed reaction runs. In the last 24 of these 100 runs, as a check on a possible olfactory cue, the old "smelled-up" path was placed at one of the wrong doors and a fresh new path was used at the right door. The percentages of correct runs were as follows: W3, 94; W8, 89; W10, 78; W11, 82; W16, 97.

CONCLUSION

With a set-up consisting of a box with three curtained doors in which rats were required to choose that door which had contained a white curtain some seconds previously, it was found that the majority of rats made at least twice as many correct runs as would be expected by chance. Checks to discover some constant sensory cue that might guide the rats failed to disclose any such clue. It is therefore concluded that the choice of the correct door was an instance of delayed reaction in the sense in which the term is commonly used.

LITERATURE CITED

[1] HUNTER, W. S.

 1913. Delayed reaction in animals and children, *Behavior Monog.*, 2:186.

[2] MAIER, N. R. F.

 1929. Delayed reaction and memory in rats, *Jour. Genetic Psychol.*, 36:538–549.

THE EFFECT OF FAMILIARITY
ON MAZE PERFORMANCE
OF ALBINO RATS

BY

GEORGE W. HANEY

UNIVERSITY OF CALIFORNIA PUBLICATIONS

THE EFFECT OF FAMILIARITY ON MAZE PERFORMANCE OF ALBINO RATS

BY

GEORGE W. HANEY*

PROBLEM

This investigation was carried on in the Psychological Laboratory of the University of California in the fall of 1929 and in the spring of 1930. Its purpose was to test further the question of latent learning. More specifically, it was to test the effect that living in a maze and running about it in a random fashion for a period of seventy-two hours, during which time no reward was given, would have upon time and error curves made by these same rats when they were later run through the maze in the usual way with a food reward at the end.

HISTORICAL INTRODUCTION

The concept of latent learning was first discussed by Blodgett.[1] He tried the effect of running two groups of hungry rats through a maze without a food reward for periods of three and seven days respectively. Hungry rats comprising a third control group were also run but were rewarded at the end of each run by being allowed to eat for three minutes in the reward box. When, on the third and the seventh day respectively, he introduced reward to the previously non-rewarded groups, he found that each group, on the day immediately following, brought its error curves to approximately the level of the error

* The author is now a member of the staff of the Institute for Juvenile Research, Chicago.

curve of the control group for the corresponding days. Blodgett removed his rats from the maze at the end of each run; hence there is the possible criticism that there may have been an element of reward even for the so-called non-reward rats in always going through the maze in the forward direction and in the fact of the mere removal from the maze and the return to the home cages at the end of each such forward run.

In our investigation the procedure followed probably guarded against any such reward factor. During the preliminary wandering period the rats of the experimental and control groups remained in their respective mazes for approximately eighteen hours for any one day period, and on removal spent at least three hours in the home cages before being fed.

Szymanski[2] performed an experiment similar to Blodgett's. He ran three rats through a maze to the home cage in which food had been placed. For the first sixty-one trials, during which period his rats were not hungry, there was no appreciable reduction in time or errors. The condition was then changed so that the rats were hungry when run. They ran the maze perfectly in one or two trials.

As to experimental approach, the investigation of Lashley[3] is more nearly like our own. One of his groups was allowed to wander about in a maze for twenty minutes before making the first test run. During the period of test runs this group was rewarded at the end of each test run. Another group, which might be designated as the uncorrected error group, was handled in the same manner as the first group save that it was not permitted to correct its errors. Still a third group was run but the incentive was different: the rat on reaching the reward box found a screen between himself and the food. Last of all, a control group was run in the usual manner, i.e., the rats gained such knowledge as they had of the maze during the test runs only. Its members were fed at the end of each test run. The wandering group did decidedly better than the control group to which no such preliminary wandering was permitted. There were but twenty-five rats in each of Lashley's two groups which

we are comparing; with a greater number of rats he might have obtained more or less significant differences between the two groups.

Our results bear out Lashley's in showing that wandering in a maze is a distinct aid to subsequent learning.

PROCEDURE AND METHOD

Groups.—The first part of the investigation was carried on at the University of California in the fall of 1929 and the second part in the spring of 1930. In each part both an experimental and a control group was used. Hereafter the experimental and control groups used in the first part of the investigation will be referred to as experimental group 1 and control group 1. Likewise those groups used in the second part of the investigation will be identified as experimental group 2 and control group 2. In each part of the investigation the order of running during the test period was, experimental group first, and then control group, i.e., all the rats of the experimental group finished their day's running before any of the control group rats were run.

Apparatus.—Two types of mazes were used. For the experimental groups a T-maze (fig. 1) was constructed of metal strips. It was made up of fourteen T-units, each section twelve inches long. At the choice points there were guillotine doors operated by means of strings leading through pulleys on the ceiling to the experimenter's control stand. These doors were employed in order to prevent rats from retracing while running the maze. Midway from the choice points down both the true and the false pathway hung black curtains, making vision to the end of the runways impossible.

During the latent learning period the maze was so arranged that rats could move about throughout the entire maze, going freely from beginning to end in either direction without being impeded by blocks. The entire maze was covered by wire netting so as to prevent the escape of the rats.

For the control groups a simple rectangular maze (fig. 2) was constructed of metal strips, the pathways being of the same height and width as in the experimental maze (fig. 1). It had
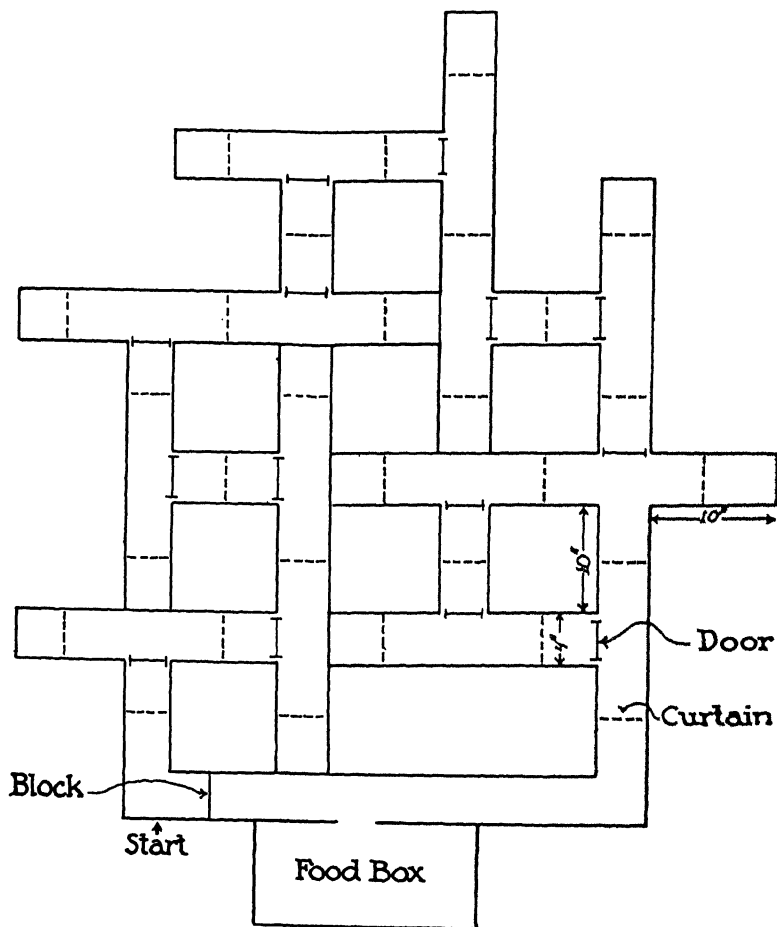
Figure 1

no culs. Curtains were hung in this maze as in the experimental maze, and it was likewise covered with wire netting in order to prevent the escape of the rats.

Latent Learning Period.—The procedure for the experimental groups was as follows: The rats of these groups were

taken from their home cages in the afternoon and placed in the experimental maze (fig. 1), where they remained for eighteen hours. The maze at this time was without the block shown in figure 1. The schedule for this group was roughly as follows: rats removed from home cages at 4 P.M. and placed in the experimental maze to remain there until 10 A.M. the following day. Three hours intervened before they were fed in their home

4′

3′4″

Curtain
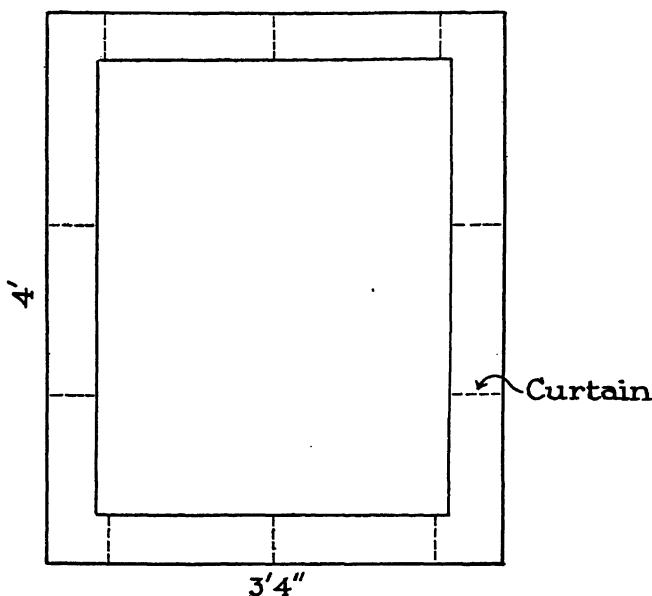
Figure 2

cages, at 1 P.M. Another three-hour period intervened before they were again placed in the maze. During the latent learning period they were always fed in the home cages and never in the maze. This procedure was repeated with this group day by day for four equal periods, or until they had spent a total of seventy-two hours in the maze.

For the control groups the procedure was identical except that they were placed in the rectangular maze (fig. 2) instead of the experimental one. The control group rats thus had an amount of handling and of experience with pathways equal to that of the experimental group rats.

Test Period.—Following the latent learning period, the experimental and control groups were run one trial per day in the experimental maze (fig. 1). The impeding block was placed eighteen inches to the left of the entrance to the reward box. With the exception of the operation of the doors, this was the only change made in this maze from its condition during the latent learning period. The doors were operated as quietly as possible and from the data and observation on the rats running, there seems to be no evidence of disturbance as a result of their operation.

Scoring.—An error was counted if any portion of the rat's body penetrated beyond the curtain in a cul. Time in seconds was counted as the rat left the entrance box and entered the reward box.

Animals.—The rats of all groups were approximately two and one-half months of age at the beginning of the experiment. All were albinos and females. Experimental group 1 and control group 1 each contained thirteen rats. Experimental group 2 and control group 2 each contained seventeen rats.

Not more than three rats were kept in any single home cage; during the latent learning period food was allotted in equal amounts to each home cage. The amount of food allotted to rats in home cages was calculated to keep the rats in good health and without loss of weight. Care had to be taken not to over-feed as this would have made the rats sluggish in their trials. During the reward period each individual rat was fed separately in the reward box at the end of the maze and every rat received the same amount.

RESULTS

Errors.—Figure 3 represents graphically the results in terms of errors for experimental group 1 and control group 1. The curve is based on the mean number of errors for the days in question as shown in table 1.

TABLE 1

MEAN NUMBER OF ERRORS FOR EACH DAY'S RUN

Day	Experimental Group 1 Mean	Control Group 1 Mean	Day	Experimental Group 1 Mean	Control Group 1 Mean
1	4.46	8.40	10	.307	1.13
2	2.61	6.26	11	.150	.73
3	.76	4.80	12	.307	1.53
4	1.46	3.53	13	.00	1.13
5	.76	2.06	14	.150	1.26
6	.84	2.06	15	.230	1.20
7	.53	2.13	16	.076	1.40
8	.61	2.00	17	.350	.53
9	.46	1.66	18	.076	.46

——— Group 1 Control
------ Group 1 Experimental
Abscissa = Days
Ordinate = Errors
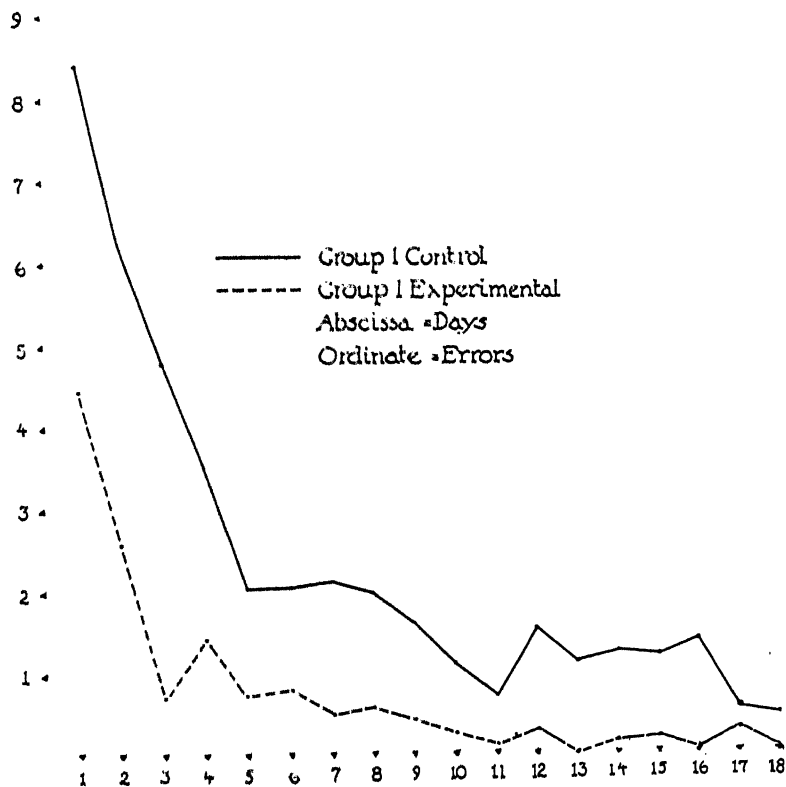
Figure 3

Figure 4 represents the error scores of experimental group 2 and control group 2. The curve is based upon the mean error scores as shown in table 2.

TABLE 2

MEAN NUMBER OF ERRORS FOR EACH DAY'S RUN

Day	Experimental Group 2 Mean	Control Group 2 Mean	Day	Experimental Group 2 Mean	Control Group 2 Mean
1	3.05	7.18	10	.76	1.62
2	3.41	6.87	11	.88	1.50
3	2.82	4.43	12	.64	1.75
4	1.76	4.00	13	.64	1.12
5	1.82	2.81	14	.70	1.18
6	1.41	2.50	15	.58	1.00
7	1.35	1.93	16	.47	.68
8	1.35	2.25	17	.29	.87
9	1.05	1.68	18	.33	.31

——— Group 2 Control
------ Group 2 Experimental
Abscissa = Days
Ordinate = Errors
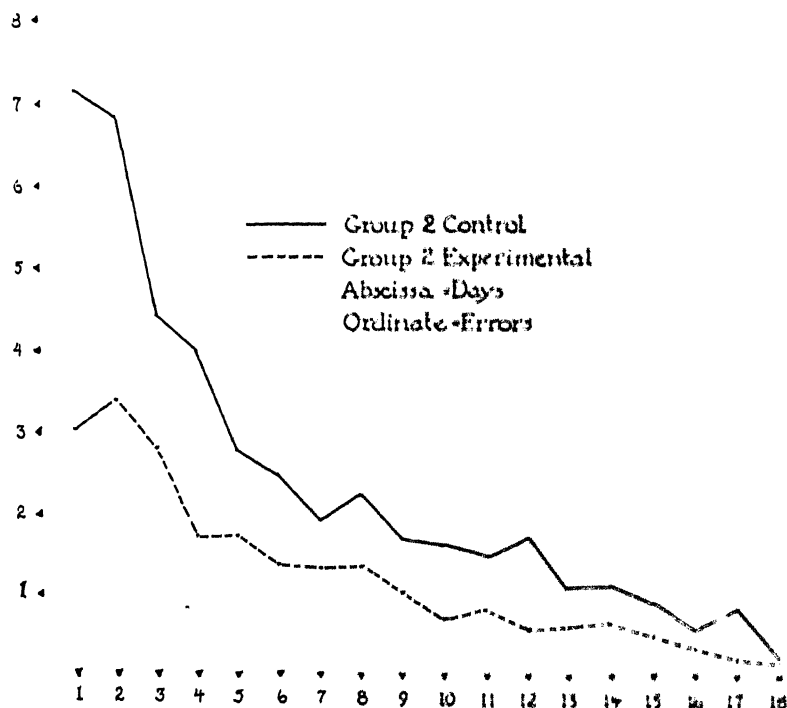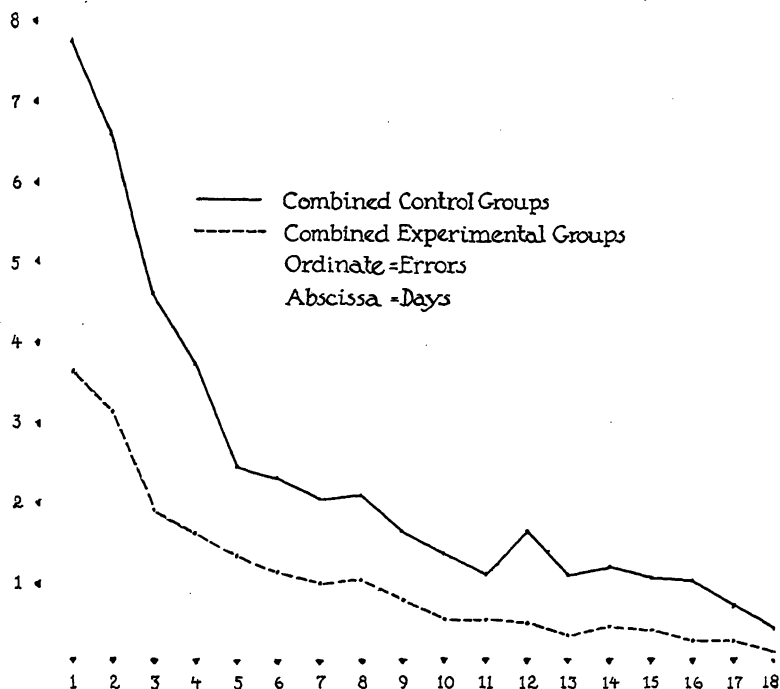
Figure 4

Figure 5

Figure 5 represents graphically the results in terms of errors of the combined experimental groups 1 and 2 and the combined control groups 1 and 2.   The curve is based upon the mean

TABLE 3

MEAN NUMBER OF ERRORS FOR EACH DAY'S RUN

Day	Experimental Groups 1 and 2 Combined Mean	Control Groups 1 and 2 Combined Mean	Day	Experimental Groups 1 and 2 Combined Mean	Control Groups 1 and 2 Combined Mean
1	3.66	7.77	10	.56	1.38
2	3.06	6.58	11	.56	1.12
3	1.93	4.61	12	.50	1.64
4	1.64	3.77	13	.36	1.12
5	1.36	2.45	14	.46	1.22
6	1.16	2.29	15	.43	1.09
7	1.00	2.03	16	.30	1.03
8	1.03	2.12	17	.30	.70
9	.80	1.67	18	.16	.38

number of errors for the combined total group for each day of running, as shown in table 3.

The per cent of the experimental group making fewer errors than the mean of the control group was, for each of the eighteen days of running, as follows:

Day	Per cent of Experimental Group doing better	Day	Per cent of Experimental Group doing better
1	96.7	10	83.4
2	96.7	11	90.0
3	93.4	12	90.0
4	100.0	13	90.0
5	80.0	14	90.0
6	83.4	15	93.4
7	86.7	16	93.4
8	93.4	17	73.4
9	80.0	18	86.7

It can be seen from this table that the degree of overlapping was small.
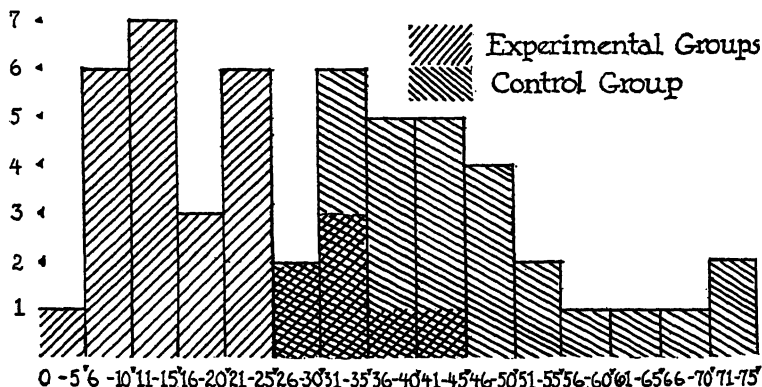
Figure 6

Figure 6 is a distribution histogram showing the distribution of the rats in terms of the total number of errors each made in learning the maze.

Using the total error data of the combined experimental and control groups and calculating for the critical ratio we have:

	Experimental	Control
Means	19.36	43.12
Sigma of Distribution	9.687	11.72
Sigma of Means	1.67	2.10
Sigma of Difference	2.68	
Critical Ratio	8.8	

The obtained error differences indicate real differences.
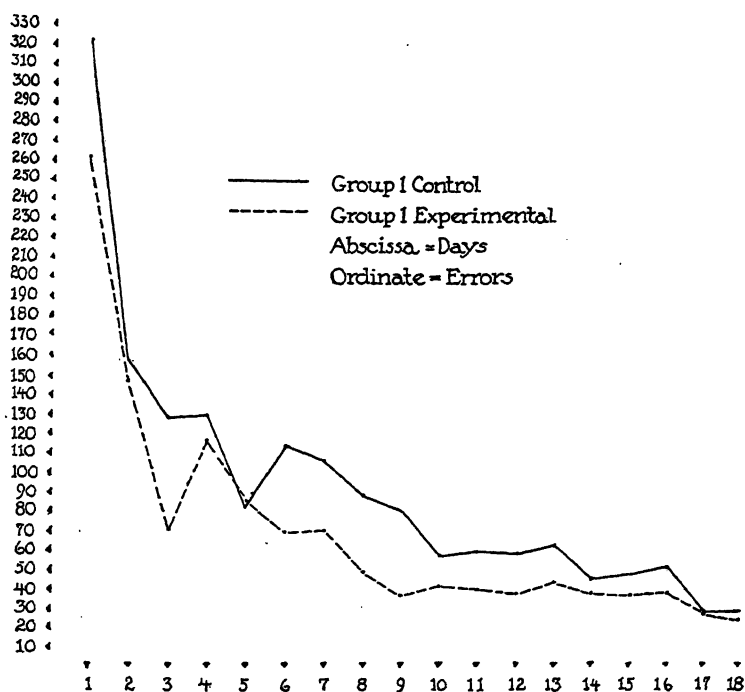
Figure 7

Time.—Figure 7 represents the time scores for experimental group 1 and control group 1. Table 4 gives the data from which the curve was constructed.

Figure 8 represents the time scores of experimental group 2 and control group 2. Table 5 gives the data from which the curve was constructed.

TABLE 4

MEAN TIME SCORES IN SECONDS FOR EACH DAY'S RUN

Day	Experimental Group 1 Mean	Control Group 1 Mean	Day	Experimental Group 1 Mean	Control Group 1 Mean
1	261.9	322.6	10	41.4	68.9
2	138.4	158.2	11	41.1	61.8
3	71.5	127.7	12	39.5	58.8
4	117.0	132.4	13	44.3	62.6
5	86.1	84.3	14	39.1	46.2
6	71.1	116.2	15	36.3	48.0
7	73.4	108.2	16	39.0	51.4
8	51.1	87.5	17	27.4	27.2
9	38.3	81.1	18	23.5	28.7

TABLE 5

MEAN TIME SCORES IN SECONDS FOR EACH DAY'S RUN

Day	Experimental Group 2 Mean	Control Group 2 Mean	Day	Experimental Group 2 Mean	Control Group 2 Mean
1	257.5	293.0	10	70.7	68.5
2	201.3	165.0	11	60.4	82.1
3	121.6	127.0	12	51.9	70.3
4	89.2	113.8	13	54.8	63.2
5	100.2	100.9	14	84.2	71.7
6	64.9	128.2	15	80.9	66.8
7	73.5	94.5	16	70.3	47.5
8	77.2	70.7	17	54.8	51.7
9	72.3	64.8	18	50.5	46.5

TABLE 6

MEAN TIME SCORES IN SECONDS FOR EACH DAY'S RUN

Day	Experimental Groups 1 and 2 Combined Mean	Control Groups 1 and 2 Combined Mean	Day	Experimental Groups 1 and 2 Combined Mean	Control Groups 1 and 2 Combined Mean
1	259.4	307.3	10	58.0	63.8
2	174.0	161.7	11	51.6	72.2
3	99.9	127.3	12	46.5	64.7
4	101.2	122.8	13	50.2	62.9
5	94.1	92.9	14	64.6	59.4
6	67.5	122.4	15	64.9	57.7
7	73.4	101.1	16	56.7	49.4
8	65.9	78.8	17	42.9	39.9
9	57.6	72.7	18	38.8	37.9

Figure 9 represents the scores in terms of time of the combined experimental groups 1 and 2 and the combined control groups 1 and 2. The curves are based upon the mean of the number of seconds which it took each group of rats to run the maze for the days in question. Table 6 gives the data from which the curve was constructed.
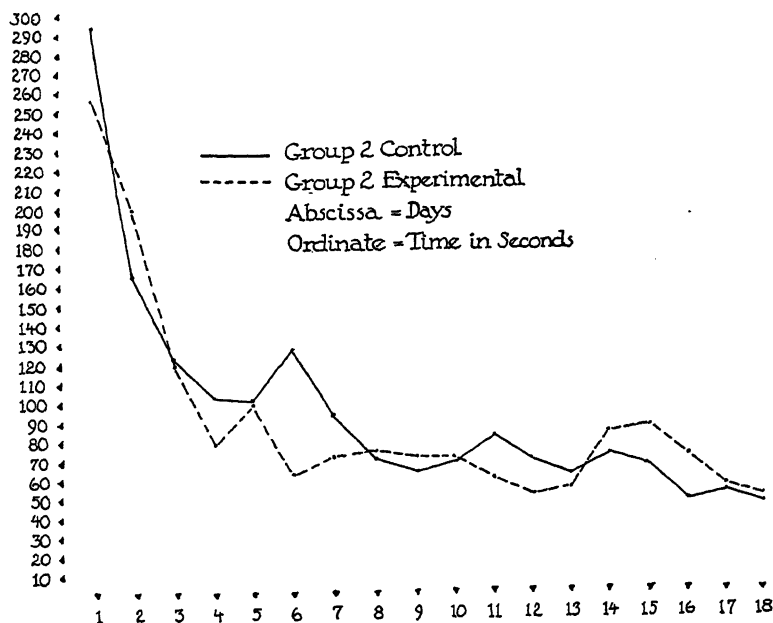
Figure 8

The per cent of the experimental group on each of the eighteen days of running that took less time to run the maze than the mean time of the control group is shown as follows:

Day	Per cent of Experimental Group doing better	Day	Per cent of Experimental Group doing better
1	70.0	10	73.4
2	67.0	11	70.0
3	67.0	12	83.4
4	76.7	13	80.0
5	73.4	14	67.0
6	86.7	15	73.4
7	76.7	16	60.0
8	73.4	17	63.4
9	83.4	18	70.0

From this it may be seen that in respect to times the degree of overlapping was much greater than was the case in respect to errors.
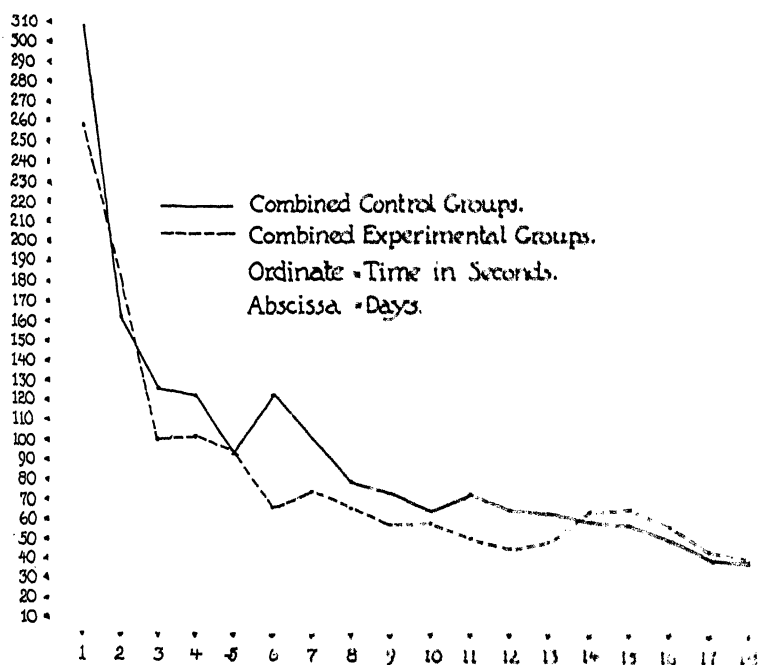
Figure 9

Using the total time data of the combined experimental and control groups and calculating for the critical ratio we have:

	Experimental	Control
Means	1467.46	1689.35
Sigma of Distribution	691.04	639.74
Sigma of Means	126.33	113.26
Sigma of Difference		169.67
Critical Ratio		1.30

Compared with the critical ratio of 8.8 calculated on error scores this ratio of 1.3 does not seem very significant.

CONCLUSIONS

1. Under the conditions of this investigation, error differences between rats having previous general familiarity with the maze and those having none, seem to be real differences. The critical ratio of 8.8 is indicative of a significant difference.

2. Under the same conditions the time score differences are not so significant. A critical ratio of but 1.3 was obtained.

BIBLIOGRAPHY

[1] BLODGETT, H. C.
    1929. The Effect of the Introduction of Reward upon the Maze Per-
        formance of Rats. *Univ. Calif. Publ. Psychol.,* 4:113–134.

[2] SZYMANSKI, F. S.
    1918. Versuche über die Wirkung der Faktoren, die als Antrieb zum
        Erlernen einer Handlung dienen können. *Pflüger's Arch. f. d.
        ges. Physiol.,* 171:374–385.

[3] LASHLEY, K. S.
    1918. A Simple Maze: with Data on the Relation of the Distribution of
        Practice to the Rate of Learning. *Psychol. Bull.,* 1:353–367.

THE ESTABLISHMENT BY RATS OF TWO CONTRARY DISCRIMINATION HABITS

BY

EDWARD L. ROSE

UNIVERSITY OF CALIFORNIA PUBLICATIONS

PSYCHOLOGY.—Warner Brown, Harold E. Jones, and Edward C. Tolman, Editors.

Price per volume, $3.50.

THE ESTABLISHMENT BY RATS OF
TWO CONTRARY DISCRIMINATION HABITS

BY

EDWARD L. ROSE

PROBLEM

Four rats were required to pass through two successive two-door discrimination boxes in order to reach food. These two boxes were identical in size, shape, substance, and general appearance. In the first box the animal had to choose the white-curtained door (whether the white curtain was at the door on the left or at the door on the right), and avoid a black-curtained door in order to gain access to a path leading to the second box. In the second box the rat had to choose the black-curtained door (whether this was on the left or the right), and avoid a white-curtained door, in order to gain access to a path leading to food. The experiment was conducted to determine whether it would be possible for the rats thus to acquire successively two contrary discrimination habits.[1]

PROCEDURE

Apparatus.—The apparatus (fig. 1, ground plan and dimensions) was constructed of unpainted redwood. It was elevated three feet above the ground and illuminated by daylight coming through large windows at one end of a white-walled room. No distinct shadows were formed in the boxes, and what shading there was, was practically identical in both boxes, since the light
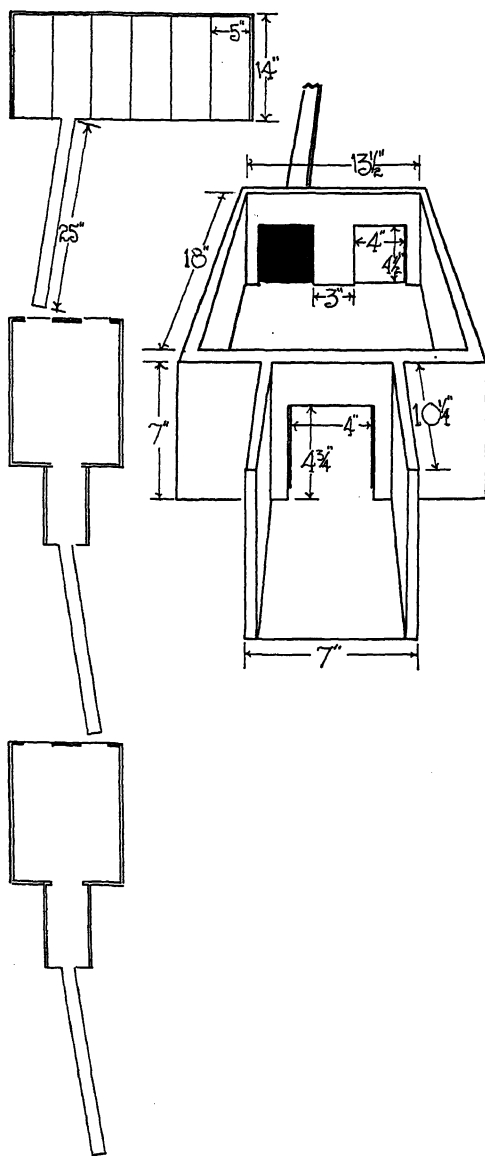
Figure 1

came to them both from the same direction and from approximately equal distances. In each discrimination box, the curtains, of heavy Canton flannel containing a light metal strip to hold them taut, reached down a half-inch below the rats' lowest vision, extended an inch on either side of each exit door, and were suspended by a wire from about an inch above the doorways. Consequently it was impossible for the rats to see under, around, over, or through[2] the curtains. Furthermore these were easily detached from their wires and the wires were easily turned on their supports to facilitate changes from one box to the other or in each box from one exit to the other. Four possible choice-

TABLE 1

Door combinations	I	II	III	IV
In the last box	Black White ↑	White Black ↑	White Black ↑	Black White ↑
In the first box	Black White ↑	White Black ↑	Black White ↑	White Black ↑

or door-combinations could be presented to the animals (see table 1). (The arrows indicate the choices to be made by the rat).

The runways were movable and could be shifted from one exit door to the other when the curtains were shifted. The ends of those leading from the response chambers were an inch below and an inch away from the doors, thus forcing the rats to push the curtains way out before they could make sure whether or not the runway was behind a given curtain. All runways were of the same dimensions and appearance, and sloped up one inch to the level of the box they led to. The final runway led to individual food chambers set in one large movable box where each rat received his entire day's feeding of bran

---

[2] C. H. Honzik, using a similar set-up for testing delayed reaction (C. H. Honzik, Delayed reaction in rats, *Univ. Calif. Publ. Psychol.*, 1931, 4:307–318), made a variety of check tests which indicated that the rats were not in any way "directly sensing" the elevated runway behind the correct curtain.

mash. A runway before the first box was included in order to make the rat's approach to that box, at least in its more immediate portions, similar to his approach to the second box. The entrances to both response chambers were equipped with wooden drop doors but these were not used during the present experiment. In an effort to eliminate any possible olfactory clues, the floors were brushed frequently and the curtains actually used were interchanged from box to box. Thus, if the four curtains used be designated as *a*-white, *a*-black, *b*-white, and *b*-black, the following four different "sets" or arrangements of these curtains were possible (table 2).

TABLE 2

Curtain Sets	A	B	C	D
In the last box...........	b-white b-black	a-white a-black	b-white a-black	a-white b-black
In the first box..........	a-white a-black	b-white b-black	a-white b-black	b-white a-black

The experimenter stood in front of the first runway three feet from the first box and seven feet from the last box during *all* runs except those when rats were punished (on 28 runs out of 892). Except for the punishments the rats received no signals from the experimenter, and by the time the series of test runnings were started they gave no evidence of being frightened by his presence.

Animals.—Four untrained male albino rats were used, each approximately seven months old at the beginning of the experiment.

Method.—The experiment consisted of preliminary training and 28 series of test runs. All the runs, both preliminary and test, were carried on at approximately the same time of day (10:00 A.M.–11:30 A.M.) and this was the only feeding period for the rats.

The preliminary training was meant to accustom the rats to being handled and to acquaint them with the conditions of the

experiment.   For three days they were trained simply to follow
along the final section of raised runway to food.   On the fourth
day they were given six runs through the second discrimination
box and over the final runway to food (no curtains being used).
Then for three days they were given runs, eight each day,
through both boxes to food (no curtains being used).   And then
for four days the rats were run to food through both boxes with
all exit doors covered with black curtains half the time and with
white curtains the rest of the time.   Then each day for four
days four auxiliary runs preceded the regular test runs which
were now also started (Wednesday, February 11, 1931).   The
auxiliary runs were like the test runs in having black and white
curtain combinations in both boxes and these curtains were
regularly changed for each run; but these auxiliary runs differed
from the test runs in having the curtains clear the floor by one
inch, in order to allow the rats to make what visual associations
they desired between curtains and runways.

On the first day of the test runs, five test runs were made; on
each of the next four days, six; and thereafter to the end of the
experiment, twelve test runs were made each day.   Sunday, Feb-
ruary 15; Sunday, February 22; Saturday, February 28; and
Sunday, March 8, no runs were made.   In each run the rats were
faced with one of the four curtain combinations shown in table 1.
On every run, in order to get through the maze without erring,
they were forced to take the white door in the first box *regardless
of its position* and the black door in the second box also *regardless
of its position*.   The rats were punished frequently though not
regularly for their mistakes by being slapped sharply on the
nose when they made a wrong choice.   All through the experi-
ment the curtains were changed from one box to the other often
enough to break down associations that the rats might make with
the specific curtains merely as such.   After the third run of test
series 27, i.e., on the next to the last day, the boxes were reversed
in position, the second box being put in the first position, and
the first box being put in the second position.   This new arrange-
ment was retained for twelve runs, i.e., throughout the remainder

of this day's testing and for the first three runs of the last day, test series 28. Then the boxes were set back in the original positions, and the experiment was continued for nine more runs. These changes in the box positions were introduced in order to detect any association that the rats might have made between local signs in the discrimination chambers and the choices of the curtains.

Scoring.—Record was kept during the first eighteen test series of errors made on every run by each rat in each discrimination box. For the last ten series record was made not only of each rat's errors in each box for every run but of door combinations within each box for each run, and of the curtain sets used.

RESULTS

The graphs (fig. 2) show for the last twenty three test series the total number of actual errors made in twelve runs by each rat in each box, and for the first five test series comparable totals (which conform to the twelve run basis) and which were estimated from real totals of errors made in the five (or six) actual runs that made up each of these first few test series. Table 3 shows, for the last ten test series for each trial, curtain combinations (I, II, III, and IV: see table 1) and also the "curtain sets" (A, B, C, or D: see table 2).[3]

---

[3] In addition to the above results, the experimenter, after examining the individual data as they were obtained from day to day, feels that the following further description of the differences of attack of the individual rats is valid and pertinent:

Rat 1 developed at first a habit of choosing all doors on the right. This continued up to test series 6. He then suddenly changed and chose all doors on the left (test series 7). This second habit gradually weakened until finally, on test series 14, he learned to choose the black curtained door in the last box, and by test series 17 had learned to choose the white curtained door in the first box. Both these latter methods, which happened to be the only ones adequate in this problem, were continued, except once when the rat neglected his business through an inexplicable lack of interest (test series 18), and again when he suffered an emotional upset and abandoned all system (test series 21). It is noteworthy that this rat (as well as rats 3 and 4) retained to the last a tendency to approach first, if not to choose first, on each run, the doors on the left. It is also noteworthy that

Final check.—On Friday, March 13, series 27, between runs number 3 and 4, the two boxes were interchanged so as to test for the rats' dependence on local signs peculiar to each box. And on Saturday, March 14, series 28, between runs number 3 and 4, they were changed back again. It will be observed from table 3 that rat 1 made an error in the box in the first position on run number 4 when he chose a black-curtained door. This might mean that this rat noticed the change in the positions of the boxes and was choosing according to their local characters, regardless of their positions, if it were not that the error was exactly like many others made previously by this rat in the first box and could very naturally have arisen from a left-door tendency; also it was the only error made in this series by rat 1. Furthermore, since this rat experienced no mental upset over the new conditions of the experiment, as was evidenced by his correct and easy running of the box in the second position, it seems permissible not to attribute any special significance to his lone error. None of the other rats made significant, seeming errors during the crucial runs.

---

the learning of the last box preceded the learning of the first box, for this rat, and that his running in the last box remained "easier" for him than that in the first.

Rat 2 early in the runnings showed real signs of discrimination. He first learned to choose the black door in the last box (test series 8) and soon after learned to choose the white door in the first box. He acquired no dominant position habits.

Rat 3 acquired early and retained for some time a left-door-position habit in both boxes. When he was eventually punished (during test series 10) for choosing a black door in the first box, he came to avoid all black doors; and then after he had returned to his left-door-position habit and (during the test series 15) was again punished in the first box for a black-door choice he finally adopted the choice of the white-curtained door in that box, while remaining for a while indiscriminate in the last box. Though this rat learned to choose correctly in the last box after he had learned to choose correctly in the first box, it was very apparent that he found running in the last box "easier" than in the first.

Rat 4 developed first a strong right-door-position habit. During test series 10 he received his first punishment, which *immediately* brought about correct choices of the white door in the first box. This developed into a technique of choosing the white door in all situations, which of course was not totally successful. By series 13, however, he had learned to choose the black door in the last box. Also at this time he built up a habit of approaching first all doors on the left.

TABLE 3

Run No.	Series No. 19			Series No. 20			Series No. 21			Series No. 22			Series No. 23		
	Doors curtains	Rats (1, 2, 3, 4) making errors First box	Last box	Doors curtains	Rats (1, 2, 3, 4) making errors First box	Last box	Doors curtains	Rats (1, 2, 3, 4) making errors First box	Last box	Doors curtains	Rats (1, 2, 3, 4) making errors First box	Last box	Doors curtains	Rats (1, 2, 3, 4) making errors First box	Last box
1	IA		1	IIIB	3		IC		1	IIA			IVA	2	
2	IVB		1	IB	4		IVC		1	IIIA			IA	1	3
3	IIIB	1	1	IIB			IIIC	1	1	IA			IIA		
4	IB	1		IA	2	1	IB	4		IVA	1 2	2	IIIA		3 4
5	IIA	4		IIIA			IID	4		IA	3		IA		
6	IIIA			IIA			IIID		1	IIB			IIA		
7	IIA	4		IA			IIIB			IIIB	4		IIB		
8	IA		1	IVA	3		IIB			IB			IIIB		
9	IVB	2		IIIC			IVD	2	1	IB	2	2	IVB		
10	IIIB	3 4	1	IC	4		IIID	3 4	1	IIB		3	IB		
11	IIB	1	1	IIIC			IIB	1	1	IVB			IIB		4
12	IA			IIC			IB			IIIA	4		IIIB	1	

TABLE 3—(Continued)

Run No.	24 Doors curtains	24 First box	24 Last box	25 Doors curtains	25 First box	25 Last box	26 Doors curtains	26 First box	26 Last box	27 Doors curtains	27 First box	27 Last box	28 Doors curtains	28 First box	28 Last box
1	IIIB	3		IIA	3		IIID	3		IIIB	1		IIIA	1 3	
2	IVB		2	IIIA			IVD			IIB	4		IIA	1	
3	IB			IA			ID			IB			IA		
4	IIB	1		IVA			IC	3		IA	3		IB	4	
5	IIIB	3		IIIA			IIC			IIA			IIB		
6	IIIB	3		IVA			IIB			IIIA	3		IVB		
7	IVA			IIIA			IIIB			IVA			IB	3	
8	IIA	2 3 4		IIA	1		IB		2	IIIA	3		IIIB		
9	IA	3		IA			IVB			IIIA			IIIB		
10	IIA	3		IB			IB			IIA			IVB		1
11	IA			IVB			IB			IIA			IIB		
12	IVA	1	3	IIB		3	IIB			IA	4	*	IB		*

———* Interchange of boxes.

Figure 2

SUMMARY AND CONCLUSIONS

Four white rats learned to choose a white-curtained door in preference to a black-curtained door in the first of two successive discrimination boxes and a black-curtained door in preference to a white-curtained door in the second of these boxes.

Interchanges between the two boxes and between the curtains used in the boxes caused no upset in the performance, a fact which eliminates any probability that the animals were depending upon secondary cues.[4]

[4] The fact that in general the last box was learned more readily than the first box may point to a theoretically important fact or it may mean merely that black curtains, as such, are more readily chosen as positive stimuli than are white curtains.

EDUCATION,—W. W. Kemp, G. M. Ruch, F. H. Swift, and L. J. Richardson, Editors.
Cited as Univ. Calif. Publ. Educ.